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THE RELATIONS OF PHYSICS AND ASTRONOMY TO THE DEVELOPMENT OF THE MECHANIC ARTS.

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It is but four months since, on the 18th of January, you celebrated the seventy-fifth anniversary of the Franklin Institute. This is, therefore, an anniversary year, and it will not be long before January of the year 1906, when you will have an opportunity to celebrate the two hundredth anniversary of the birth of Benjamin Franklin, whose name is held in reverence and inscribed above your portals.

You now propose to inaugurate a new branch of activity for the Franklin Institute. Not long since you added the Mechanical and Engineering Section to those already existing, and you have now added a fifth, to be entitled "The Section on Astronomy and Physics." The organi-

zation of the Franklin Institute will, therefore, hereafter include, not merely a "Committee on Science and the Arts," and "Sections on Engineering and Mining and Metallurgy," but also special sections on important branches of science, such as astronomy, general physics, electricity and chemistry.

You have thus recognized the existence of certain relations between the advanced sciences and the practical arts. The Franklin Institute is devoted primarily to the promotion of the mechanic arts, but you have recognized that the sciences are so closely related to the mechanic arts that it is to your advantage to give them a distinct recognition in your organization.

I. THE MECHANIC ARTS CLOSELY RELATED TO PHYSICAL SCIENCES.

This inaugural meeting of your newest scientific section is, therefore, an appropriate occasion on which to consider with some detail the precise character of the relation between physics and the mechanic arts. I do not say astronomy and physics because that branch of astronomy which we shall consider is itself known as celestial physics. We have celestial and terrestrial and molecular physics, three branches of knowledge that are all included under the comprehensive term *physics*, or the science that treats of *force*. Ages ago man recognized only those forces in which large masses of matter are involved. He studied projectiles, falling bodies, the equilibrium of forces, the buoyancy of vessels, the motions of waves and tides and winds, and even the motions of the heavenly bodies. But now he has learned that all chemical phenomena have to do with the motions and equilibrium of molecules; that heat and light and electricity and the photographic or chemical action of light are but the motions of individual molecules of ponderable matter, and of the imponderable ether atoms that drive the material molecules hither and thither; that sound is but the motion of larger groups of molecules. Everywhere he is confronted by the laws of force.

If you strike a smart blow with a hammer upon the

head of a cold chisel and make a cut into a piece of soft iron, you are doing one of the simplest mechanical operations, and yet you are awakening a long list of reactions that invade every branch of physical science:

(1) The muscles respond to the eye and the will; the hammer moves with great acceleration and strikes straight and hard; the energy of the blow comes from the chemical transformations going on within the workman's body, suggesting problems that belong to the profoundest depths of biology.

(2) The stroke of the hammer calls forth a clear and cheerful sound from the head of the chisel—a musical ring with all its problems in acoustics.

(3) The hammer, the steel chisel, the soft iron and the chips become warm and hot under the repeated blows, suggesting problems in thermodynamics and the radiation and conduction of heat.

(4) The edge of the hard chisel becomes dull, but a deep gash is cut in the soft iron; eventually the face of the chisel breaks; all of which results are explained by the study of the science of elasticity as applied to the flow of solids and the exhaustion of metals.

(5) A better chisel is picked out and the hammering goes on all day without harm to the tool; such choice could not be made without a thorough knowledge of the chemistry and physics of steel.

(6) If the anvil be a stone and both it and the hammer be properly insulated and connected with an electrometer, every stroke would be seen to produce electricity; this sets us to thinking about piezo-electric phenomena, and we perceive that as every change of pressure produces electrical phenomena, therefore the electrified condition of the whole earth, with its resulting atmospheric lightning, may be in part the result of the crunching of the geological strata that we call the earthquake, an idea that was first suggested by Clerk Maxwell.

I need not weary you with illustrations of that which must be patent to every thoughtful mind; the general principle holds good everywhere and at all times that no inven-

tion can be made, no action taken, no great work accomplished on this earth, without involving many principles in nature that have already been recognized by scientists and others that still remain to be discovered.

You, therefore, do well to combine both physical science and the mechanical arts into one institution. Your object must be, on the one hand, to apply physics to the proper construction of machines and the daily needs of the artisan; on the other hand, you may hope to add something—perhaps much—to our knowledge of physics, through your ingenious machinery, your abundant experience and your keen thought.

The manifold and intricate connection between the sciences and the arts may be treated from several points of view. Let us first glance at the historical development of this connection.

II. EVOLUTION OF THE MECHANIC ARTS.

The mechanic arts may be said to have existed before the dawn of history; they were coeval with the evolution of the Aryan language. We trace the art of weaving, as we now know it, back to the time, 3,000 years ago, when it was already well advanced in India, but the word *to weave* is far older than that. We trace the potter's wheel back to the earliest archæological potsherds, perhaps 5,000 years, and know nothing of its far earlier history. We trace the arts of cutting, sawing and planing from our present magnificent machinery back to the first knives of jade used by the prehistoric Asiatic and American races. We trace our hoes, ploughs and cultivators back to the sticks and the forked branches that were used to scratch the soil by the first tribes of men, but how many thousand years ago no one ventures to say.

The modern railroad car, the elegant wagons and the fleet bicycles only became possible after the ancient architects had first learned to put rollers under the massive stone blocks and had put rude wheels to the carts drawn by oxen and to the wheelbarrow pushed by man.

The art of sewing leaves together, or that of spinning

threads must have been an early suggestion after man had learned to twist grass and twigs together to form crude ropes.

Our extravagant military engines, from the immense ironclads down to the Mauser rifles, go back step by step to the stones and slings, the bows and arrows, and the boomerangs of primitive man.

I should say that the mechanic arts had no definite beginning; they have gone through a process of evolution so gradual and gentle that we can at no time say "this was the beginning."

Mythology does, of course, tell us that Vulcan forged Jove's thunderbolts. To the mind of the child of to-day, just as to the childish minds of antiquity everything on earth must have had a definite beginning, there must have been some one who first taught us how. Therefore, the ancients demanded a cosmogony, a History of Beginnings, a Divine Creator and a simple tangible method of procedure as to His inventions and creations.

But the modern scholar who has studied carefully all the ways of nature among the plants, animals and rocks of this earth and the stars of the universe beyond us, perceives that a series of changes, a gentle and gradual evolution, has prevailed everywhere. We are, therefore, prepared to recognize that this same principle applies to the industries and to the arts that have been developed through the agency of man. We are but the agents. The Creator is working, but through us, not for us. He moulds the world, not as the potter does the inert clay, but as the wise parent does the mind of the intelligent child.

III. EVOLUTION OF INVENTIONS.

The crude devices of primitive man were improved by successive inventions. In the history of invention, properly so-called, the simple collocation and juxtaposition of two ideas is often the critical matter. It is not science, or study, or art—it is simply the happy accident that brings some one's mind two thoughts that are suddenly seen by the inventor to have an important relation to each other,

hitherto unsuspected. For instance, some one is anxiously looking about for a pigment that will produce a special tint of color. He is wandering along the roadside and sees the color he needs in a piece of stone or discoloring a ledge of rock. If his mind is ready to receive the suggestion, it becomes seed sown in good ground. The idea of grinding that stone into pigment immediately occurs to him. He proceeds to experiment, and not only grinds, but oxidizes and even roasts the stone. The invention was a matter of suggestion to the inquiring seeker, but the art was an application of physical and chemical science.

Man's needs have stimulated him to discover and invent. Those who enjoyed the best surroundings have generally brought forth the best results. Those nations and individuals who were unfortunate as to climate, soil, vegetation, minerals, water-power, etc.—those who had neither stimuli nor opportunities, did little. In proportion as we to-day associate ourselves with the highest science, we bring forth the best inventions and manufactures.

Some one asks why we cannot make a steamboat that will go fifty miles an hour by the use of the screw-propeller. The idea is good, but it is a mere matter of imagination, a dream, a useless suggestion until all the resources of physics and mechanics have been combined to evolve the modern high-speed vessel.

Professor S. F. B. Morse was an artist, but was also seeking to make some great invention. The idea of communication by means of electricity, with the speed of thought, early took possession of his mind and he was always on the look-out for some method of realizing the indefinite hope that haunted him. Ten years were spent in making every conceivable combination of electrical devices—but nothing came of them. At length Dr. L. D. Gale suggested that Joseph Henry's recent researches on the electro-magnet be put to use. That distinguished scientist was consulted at Princeton, and immediately it was found that the laws that he had discovered in relation to electricity and magnetism, and the apparatus that he had made were those appropriate to the Morse telegraph, that, in fact, he had one already at

work. Even if you do not agree that we ought to speak of the "Henry telegraph" and the "Morse alphabet," you will at least grant that every step in telegraphy, from its beginning to the modern perfection of the art, has only become possible by means of the knowledge resulting from investigations conducted by scientists, or by inventors who had to become scientific investigators before they could complete their work.

IV. INVENTION ASSOCIATES WITH INVESTIGATION.

We must be careful to recognize that the inventor is frequently also a scientist, and still more frequently is the scientist an inventor. The scientist cannot investigate without having instruments and apparatus, and must invent these to suit the needs of the case. The inventor frequently comes upon an obstacle that cannot easily be overcome until he has investigated some obscure point either in mechanics or physics. This principle is beautifully illustrated by the life and work of James Prescott Joule, who was the son of a brewer, and himself continued in that business for a long time. His scientific education under Dalton, in England, and Jacoby, in St. Petersburg, enabled him to fully appreciate the mutual relations of science and art. While others speculated on the use of the electricity from the galvanic battery as a motor, he, by studying the laws of thermodynamics, showed the exact connection between the amount of work that could be done by a pound of coal when burned in the furnace and a pound of zinc consumed, *i. e.*, burned, in the galvanic battery. He then proceeded to the determination of the so-called "mechanical equivalent of heat," viz., the fact that a unit of heat can only do 772 foot-pounds of work. He is justly considered one of the founders of the modern doctrine of the conservation of energy, whose principles must be obeyed by every mechanical device that man may invent. When anybody proposes to manufacture something out of nothing, no matter whether he calls it perpetual motion, or the Keely motor, or the liquid air motor, you have only to show him that he proposes to violate Joule's law and he must subside.

The changes of temperature produced by the condensation and rarefaction of gases, especially of steam, are vital to the working of the steam engine. These were early experimented upon by Espy, but more thoroughly by Joule and Kelvin; the arrangement of the cut-off of the steam engine must be made in accordance with Joule's laws if the machine is to work efficiently, as indeed he, himself, first showed in his paper of June, 1844. At that time he said: "The principles I have established lead to a theory of the steam engine very different from the one generally received. . . . Believing that the power to destroy belongs to the Creator alone, I entirely coincide in the opinion that any theory which, when carried out, demands the annihilation of force, is necessarily erroneous. . . . The theory here advanced demands that the heat given out in the condenser shall be less than that communicated to the boiler from the furnace in exact proportion to the equivalent of mechanical power developed."

V. MECHANICS, EXPERIMENTAL AND EMPIRICAL, ASSOCIATES WITH SCIENCE.

I choose the following case to illustrate this theorem:

In the "Philosophical Transactions of the Royal Society of London," for 1886, is a beautiful memoir on the theory or method of action of lubricating oils and other lubricators. This memoir, by Professor Osborne Reynolds, seems to be the first satisfactory effort to unravel the physical actions involved in lubrication. There had been abundance of previous experimentation for two hundred years past, and many empirical rules and tables had been formulated, respectively applicable to each set of experiments, but the special experiments made by Mr. Tower gave Professor Reynolds the first suggestion as to the truth concerning the method of action of the film of oil that we insert between a journal and its bearings, in order to diminish the loss of power by friction. Reynolds had previously conducted a beautiful set of experiments on the flow of liquids in tubes and very small channels, and had shown that, although the resistance to flow is ordinarily proportional to the square of the velocity,

yet there is a critical velocity at which it suddenly changes from the square over to the first power of the velocity. He was now able to show that lubrication is simply a case of the flow of a viscous liquid through a very narrow channel. When the journal presses upon its bearing, the intermediate space is perhaps the $\frac{1}{1000}$, or more likely $\frac{1}{10000}$ of an inch in thickness. This space, being filled with oil, constitutes the thin film that serves to convert the rubbing and tearing of the metals into the sliding and rolling of liquid molecules. It is as though we had inserted a myriad of minute steel friction balls between the journal and its bearings. You are all familiar with the thin films of the soap bubble. Perhaps you have observed that when the film is not too thin it may be said to consist of two surface films separated by a thicker layer of liquid. These two surface films may slide past each other. By careful watching you may see the beautiful spots of colored light rearranging themselves as the two surfaces draw nearer and nearer together and squeeze out the liquid between them. The thinnest part of the soap bubble is a film much thinner than that ordinarily dealt with in lubrication, while, again, the thicker parts are much thicker than lubricating films. By means of the apparatus invented by Plateau the properties of these thin films have been abundantly studied. The motions of the viscous liquid particles must obey the laws of mechanics, as at first clearly expressed by Stokes, Kirchhoff, Helmholtz, Stefan and other students of hydrodynamics.

The results of these difficult researches in molecular physics have a direct application to the lubricating action of oils. Professor Reynolds succeeded in elucidating the novel phenomena recorded by Mr. Tower and established an important verification of the assumptions on which our modern theories of hydrodynamics and molecular physics are founded. I may be allowed to speak more fully on this subject, because these ideas have not yet found their way into many text-books on machinery. Let us take up one simple phenomenon, viz., the heating of the journal and bearings. We have hitherto imagined that after the jour-

nal has worn a smooth bed in its bearings, and there is no objectionable and injurious heating or abrasion, that then its rapid revolutions proceed without the evolution of much heat. Now the fact is, that while the upper and lower surfaces of the lubricating film of oil remain in permanent contact with the steel journal and the brass box, respectively, or at least change very slowly and there is no abrasion of the metals, still the thin layer of intermediate liquid is being rapidly torn away and renewed. The viscosity of the liquid resists this sliding of one layer of its molecules past the other, and thus gives rise to heat; the inner layer of the liquid film soon becomes a surface layer where the molecules are under great tension, and this change gives rise to more heat. As long as the journal is revolving heat is being evolved by the compression and internal friction or motion of the molecules composing the lubricator itself. Often we do not observe this heat because it is carried away by conduction through the metals and by the least breath of air almost as fast as it is generated. Every one knows that the abrasion of dry metal surfaces evolves heat—but the abrasion of viscous films also does so. As the journal revolves rapidly it carries its thin film of oil into the crevice between the journal and the bearing; it is a V-shaped or wedge-shaped crevice, and as the film crowds into the wedge Reynolds speaks of it as going into the "on" side, because right above this crevice is the load bearing down upon the film. As the film squeezes through the crevice, being forced along by the rotating journal, it quickly approaches the off side of the load, where the pressure is taken off of it and it is again free to spread out over the journal; thus it is carried around until it again enters the "on" side and squeezes through a second time to the off side. You will see at a glance that the small area of film between the journal and the bearing on the "on" side must support the whole load, and this implies an enormous pressure, which, in the experimental work of Mr. Tower, was only 625 pounds to the square inch, but must be far greater than this in many of the cases that occur in actual practice. Of course, the laws that hold good for perfect

lubrication will not obtain for the case of imperfect and irregular supply of oil, or for cases where the lubricant has not the proper molecular and physical properties needed when very great pressures are involved. But when there is a full supply of oil and the pressures are not too excessive, then you will easily perceive that the film adhering to the journal and about to enter the "on" side of the crevice is not as yet under any pressure or constraint, except only that it is held to the surface of the journal by reason of some molecular attraction between the metal and the liquid. Ordinarily, we say that the particles of liquid cohere among themselves, while the liquid and the solid adhere together. Now, the liquid will not easily be forced from the free surface of the journal into that crevice between the journal and bearing where the pressure per square inch is so great, and yet it does both enter and pass through, and there is nothing to bring about this remarkable result, except the rapid motion of the journal and the adherence of the film to its surface. We must think of the liquid film as a small mass of matter thrown into the "on" side of the crevice with considerable velocity and, also, as dragged in by the journal. Its viscosity and its inertia combine to force it into the wedge-shaped space. It must be very considerably compressed therein. It must, also, have its molecules forcibly squeezed past each other as it passes through the narrowest part of the wedge and slips onward to the large space in the rear. Of course, also, its forward movement with the journal is slightly retarded in front and accelerated in the rear. But the most interesting feature is the pressure—the static pressure within every part of the film.

There must be a resultant pressure against the surface of the bearing and another against the surface of the journal. These would be normal to the surfaces and equal in intensity and opposite in direction if the journal were not in rotation, but when rotating, the pressure keeping the two surfaces apart is greatest in the front half of the lubricating film, while in the rear half it becomes negative, that is to say, it tends to bring the two surfaces together. This sur-

prising result may, perhaps, be easily reconciled with our current ideas if we remember that the same powerful adherence which carries the oil with the journal forward into the funnel must also, in the rear of the latter, carry it away from the funnel. As much oil must leave the funnel in the rear as approaches it in front. There is a push in front, but an attraction in the rear. It is evident, therefore, that the force that keeps the journal from absolute welding contact with its bearing is the adherence of the oil to the journal and the coherence of its own particles. The resistance that we call friction in a smooth-running journal is an exaggerated case of that which we call viscosity in hydrodynamics. It is the force required to make one layer of liquid glide past another.

The other friction that occurs when no lubricant is used, or when the supply of the lubricant is too limited, of course, involves the tearing asunder of the particles or molecules of the metals themselves. This abrasion is not considered in the theory of lubrication.

Professor Reynolds' hydrodynamic theory, as checked by Mr. Tower's experiments, seems to give us a complete statement of the relation between the frictional resistance, the load and the speed for any lubricant that is supplied in abundance, and he has given us a general formula applicable to all cases that can occur.

When there is but a limited amount of oil available, an increase in the load, *i. e.*, the pressure, will diminish the thickness of the film around the journal in general, but will increase the length of the pad of oil that bears the weight, thereby increasing the area of the surface films, whose sliding past each other produces the frictional resistance, and, therefore, increasing the friction. The relation between the increase in friction and the increase in load for this case is more complicated than for the case in which an unlimited amount of oil is available, which latter case is experimentally realized by wholly immersing the journal and its bearings in a bath of oil.

The result of the whole research is to show that, not only in case of intentional lubrication, but whenever hard sur-

faces under pressure slide over each other without abrasion, they are separated by a film of some foreign matter, whether perceivable or not; that the action of the revolving journal is to maintain the film between the surfaces at the point of pressure; that if there is any abrasion when the surfaces are well lubricated and well filled, it must be due to the foreign particles in the oil—particles introduced at the first grinding or subsequently as dust.

I may add that when the lubricant has thickened or is entirely absent, we have a condition analogous to that of the swiftly revolving wheel of soft lead, which is used to cut into the harder metals, to which I will refer later.

I give this long review of Reynolds' work as but one among many illustrations of the advantages that accrue to empirical mechanics when illuminated by sound science.

VI. SCIENCE STIMULATES THE MECHANICAL ARTS.

The demand for measurements of the highest attainable accuracy is characteristic of the study of astronomy and physics, and always keeps in excess, or, more properly, in advance, of the current state of the art of construction. Consequently, the needs of science have made many demands upon the mechanical arts, and have steadily stimulated their progress. Science and art mutually stand to each other as cause and effect. The demand has always exceeded the supply. The supply has always, eventually, responded to the demand. The patrons of physics, and especially of astronomy, have always been willing to pay for the highest art, and no instrument-maker of genius has labored without abundant recognition.

Consider the manufacture of optical glass, which has reached its highest development in such works as those of Chance & Co., Feil & Co. and the School of Glass Technology establishment at Jena (under the control of Schott and Prof. Ernest Abbe). Here are manufactured great plates of optically perfect glass, having any required characteristic as to refractive and dispersive power, or even as to elastic and electric properties.

The construction of telescope lenses as perfected by Al-

van Clark, and of microscope lenses by many artists too numerous to mention, all involve mechanical processes of the rarest delicacy, and illustrate how perfectly one class of men, the mechanicians, have been able to realize the ideals conceived by another class of men—the investigators.

The mounting of the great steel tube and all the accessories of the telescope, the construction of the revolving dome and the movable floor by such firms as Warner & Swazey, all demand the best engineering, while the delicate micrometer, with its perfect measuring screw, the spectroscope, the photometer, the camera, the chronograph and the clock, the transit instrument with its perfect pivots, the vertical circle with its delicate graduations, the altazimuth instrument and the spirit-level on which everything depends, each and all call for the most delicate manipulation, the most absolute homogeneity of material, freedom from internal strain, the finest work with the lathe, dividing and planing machines and numerous other characteristics of the highest type of the mechanical arts.

For two centuries past the stationary astronomical clocks and, especially of late years, the portable chronometers used by navigators at sea, by explorers on the land, by geodesists and astronomers everywhere, have been reckoned among the marvels of mechanism. Hundreds of men have directed their best thoughts to the perfecting of these time-pieces, so that they shall respond to the needs of the practical astronomers. From this work has resulted the possibility of the establishment of the manufactories of high-class watches on an immense scale, so that now every one purchases, for a few dollars, that which a century ago it was entirely impossible to obtain. We wind our watches daily and boast of their accuracy to within a few seconds, quite forgetful of the fact that the astronomer and mechanician had to combine together to evolve this great system by which a million of time-pieces of high character are annually manufactured for popular use. But, not satisfied with this, the scientist takes the most perfect specimen of all these and uses it in pushing his astronomical studies to a still higher perfection.

Astronomy is often called the parent of all the sciences, because it is said to have been the first in the order of development. But it has also been the foster-parent, because astronomers found it necessary to develop, encourage and protect every other branch of science in order that their own might prosper. Astronomy has demanded the most perfect apparatus. The command of large funds consecrated to this work by generous patrons has enabled astronomers to stimulate active minds and nimble fingers so as to secure those triumphs of accurate workmanship that are necessary to the advance of every branch of science. In this way the sextant and chronometer came to be devised for the navigator; the theodolite, the base apparatus, the pendulum apparatus and the spirit-level were devised for the use of the geodesist; the Gaussian apparatus for the study of terrestrial magnetism; the modern balance for the use of the chemist; the self-recorder for the use of the meteorologist.

When the investigator needs better apparatus, he usually invents or designs its necessary features and then calls in the mechanician to help construct it; the former discerns the sources of error and the latter devises methods to overcome them. Generally, the student leads the mechanician; science directs the art of the mechanic; the mind guides the hand.

The popular idea of science includes both the increase and the diffusion of knowledge; to the general English reader the scientist may be either a discoverer, an investigator or a teacher. But the teacher cannot exist without the discoverer. Since the investigator must add to the sum total of human knowledge in order that the teacher may have something to teach, therefore, he must know both what has been done by others and, also, how to improve upon that. He, therefore, it is who is the true inventor, the one who *finds out;* and it is he who in his desire to study deeper stimulates the mechanic to produce better tools and apparatus. Thus it is that both the astronomer and the physicist and all the special students of nature take a prominent part in the development of more perfect apparatus.

They must have the means to make better measurements of length, area and volume, of time, velocity and angle, of weight, mass, attraction and repulsion, of electrical current and resistance, density and potential, conductivity and capacity; of temperature and heat, expansion and radiation. They must have all the apparatus especially appropriate to the study of heat and light, elasticity, gravity and electricity. The best they have to-day will not be good enough for to-morrow.

VII. FUNDAMENTAL IMPROVEMENTS IN MACHINES FOLLOW THE DEVELOPMENT OF FUNDAMENTAL PRINCIPLES IN SCIENCE.

Every important advance in the mechanic arts has been preceded by special scientific investigation and the determination of data that were fundamentally necessary to the success of that particular advancement. This seems like a very strong and, perhaps, a rash statement. I may not have made an exhaustive examination of the subject; there may be an exception to the rule; but we shall find so many illustrations of its truth that we must accept its general application in modern times, whatever may have been true in the earliest stages of the arts. At the present time, those whose tastes incline them to research pave the road for those whose tastes incline them to invention and manufacture. The heroes of invention and manufacture would still be lost in the wilderness of ignorance had not the devotees of science prepared a highway and paved it with a solid Belgian pavement of blocks of knowledge on which all may march to success.

I will illustrate this by, first of all, considering the subject of the efficiency of a machine.

In the construction of a tool or machine every device has for its object to secure the attainment of some specific motion or result with the greatest possible economy of force, in the least possible time, with the least possible waste of material. The original source of our power may be falling water or tidal waves, the burning of coal or the consumption of some precious metal, it may be the wind or

the direct energy of sunlight, or that indirect effect of gravitation represented by the electric currents that flow through the earth and atmosphere. In extreme cases, we may go back to the old-fashioned sources of power, the horse, the dog or the man working in a treadmill, or travelling round and round in a circle. But in every case, we nowadays have to compute the ratio between the cost of the power and the value of the work that we finally get out of it. This involves essentially the question of the relation of the motor power itself to the amount of resulting work. This latter ratio we call the mechanical efficiency of the machine; the perfect machine of modern times is characterized by a large per cent. of efficiency. For instance, we use an axe to split logs of wood. A dull axe, or one whose blades are rough or wrongly inclined to each other, will waste a large percentage of our strength in friction and unnecessary resistances. After we have given it a sharp edge and a proper angle of cleavage, we still have to consider the ratio of its weight or mass to the power available in our muscles and the resisting power of the log that is to be split. With a small mass in the head of the axe, such as 3 to 5 pounds, we should in vain attempt to cut the tough wood that would yield to a heavier axe of from 5 to 7 pounds.

Among our natural sources of power we reckon the wind as one of the earliest to be used and still one of the most important. To increase and to measure the efficiency of a windmill is a problem that has taxed the genius of our best inventors and students. It is not measured by the quantity of work done per hour, but by the ratio of that to the work done by the wind in passing between the sails of the windmill. Having given up some of its momentum to the sails, the wind must still retain a large portion in order that it may move onward and make room for a fresh supply of air that is coming onward from behind. It would not be advisable to abstract from the wind more than one-half of its momentum, therefore, from this point of view, the efficiency of the windmill sail should not exceed 50 per cent.; this is the external efficiency of the mill. If now we compare the

work done at one end of the machine with the energy of the revolving windmill-sails at the other end, we obtain the internal efficiency of the mill, which in properly constructed apparatus may be as high as the factor for the best machinery of any other kind; but in fact, the windmill is not generally constructed with great care, and Prof. Franklin B. King, of Madison, Wis., finds but a small percentage for the best windmill investigated by himself.

The mechanical efficiency of a machine is now recognized as a matter of the very highest importance. Much of our manufacturing competition is based upon the relative merits and relative expenses of running our machines. The modern methods of measuring efficiency and of investigating the sources of waste emanate always from those who are fully alive to the laws of force involved in all mechanical operations. They are essentially due to the physical laboratory and the mechanical laboratory. They often involve mathematical considerations of a very abstract character. Many an engineer keeps the records of his indicator card and sums up the foot-pounds per minute in a mechanical sort of way that shows that he can have no conception of the labor given to the study of thermodynamics before this simple device could be made equally useful to the manufacturer and to the inventor. The former sees in it a record of how much his engine is wasting, the latter sees in it suggestions as to how to improve the machine. The indicator card is an application of physical laws to practical machine work that has during the past fifty years been quietly revolutionizing the construction and use of the steam engine.

The injector first made by Giffard, a French engineer, which, by the way, has received numerous important modifications by William Sellers & Co., of Philadelphia, must be allowed to be not an efficient machine from a mechanical point of view. But, from a thermal point of view, it is almost perfectly efficient, since all the heat of the steam and the feed water goes back into the boiler; it is this that enables it to add to the efficiency of the steam engine as a whole.

The Bessemer process for making steel is a good illus-

tration of a method that is highly efficient mechanically, thermally, chemically, and I may also say chronometrically, since the time required is reduced to a minimum, consequently also financially, and it is no wonder that we have now suddenly arrived at the age of steel as distinguished from the age of iron.

The process of welding by means of the electric current is another illustration of an economy of time, fuel and power that is truly remarkable. You will perceive that all these improvements were preceded by a long series of laborious scientific determinations of the necessary fundamental data.

The pumping of water by means of reciprocating force pumps, as distinguished from the rotary pumps, is a very ancient process, the crudeness of which, from a mechanical point of view, might have been thought to have been overcome by the rotary and centrifugal pumps. The reciprocating pump is still indispensable when great heights or resistances are to be overcome; but it is precisely also in this case that the strains upon the machinery are most dangerous to its welfare. Here come in the improvements made by your fellow-member, Mr. D'Auria, whose devices have overcome important difficulties experienced in other machines, while at the same time he attains a remarkably high percentage of mechanical efficiency. If his construction of tubes and his arrangement for the flow of water and diminution of shocks is properly analyzed, it will, I think, be seen to be the outcome of a long study into the flow of water in rivers and channels. His application of theoretical hydrodynamics to the construction of pumping machinery is a fine illustration of my general principle that all the higher improvements that our present types of machines have received or are still susceptible of, in order to become more perfectly efficient, can only come from that profound study of mathematical and physical principles that belongs to the scientific and technological courses of our universities.

If any further evidence were wanted, you have only to consider the other side of the case, viz., the fearful sacrifice of time and money, human thought and human life that is

represented by the thousands of useless devices that are annually patented by over-sanguine inventors. These usually proceed from men of little education or experience, who have heard, perhaps, that John Smith made a fortune out of his little invention, and vainly imagine that whatever is new and patentable is naturally of some value.

It would be impossible to quote to-night all the important inventions, even by members of the Franklin Institute, that illustrate the importance of economy and efficiency as the prime characteristic of any great invention, but I will mention, still, the brilliant invention of the sand-blast by Mr. B. F. Tilghman. This simple jet of air or steam with sand does in a few minutes the work of cutting that the finest engravers might spend years in doing. It substitutes machinery for the engraver's hand; but, of course, it cannot replace the artistic imagination of the famous cutters of gems. The mechanical principles involved in this process were explained by Professor Osborne Reynolds in the *Philosophical Magazine* for November, 1873. The first and fundamental item is a law of impact, viz., that at the instant of first contact the pressure between two bodies is independent of their size, their mass or their velocity, but depends principally upon the density of the bodies and their hardness, so that a dense soft body may cause as much pressure as a less dense but hard body.

Singularly enough, very much the same principle applies to the soaring flight of a horizontal plane surface flying through the air. If the plane were to fall vertically from rest to the ground, it would quickly set all the air below it in motion outward in all directions, and would fall more rapidly because falling with the moving air; but, when flying horizontally, it experiences at every moment the necessity of giving motion to a fresh mass of quiet air. It falls more slowly, as if experiencing a greater resistance. In this way, the air, considered as a soft body, causes an upward pressure sufficient to support a heavy body for a long time. So in the sand-blast, the first effect of the impact of the grains of quartz is to impress on the molecules of the softer glass a slight motion, which is a certain percentage

of the movement of the harder particles of sand, and just sufficient to tear them away, one at a time, from the rest of the glass.

You will perceive that Reynolds' law applies again to the polishing burr-wheel, to the spinning of sheet iron and tin plates and to the cutting of stones, metals and glass by the edge of the rapidly-revolving wheel of soft lead or copper.

Professor Reynolds shows that, in order to produce the same effect, a sand-blast that is cutting into lead must have a velocity about eight times as great as when cutting into glass, the ratio depending upon the relative densities of the lead and glass.

The geologist has occasion to apply these same principles, since the sand-blast is always at work eroding the face of the earth with the help of wind and water.

I cannot refrain from quoting another modern invention that illustrates the recent application of simple physical principles to machines. I do not know the personal history of the inventor of that which we call the "Babcock Cream Separator," but he must have been a student of physics who first proposed to substitute centrifugal force for the force of gravity. As you all know, the particles of cream rise to the surface of quiet milk because of their buoyancy. Cream is specifically lighter, or has less density, than water. Gravity pulls down the water harder than it pulls the milk, and therefore the water pushes the cream up by a hydrostatic pressure that it owes to the attraction of gravitation. Mr. Babcock puts his milk into a rapidly-revolving cylinder; the rotation gives rise to a centrifugal force, all particles have the same rotatory velocity, but, each particle of water being denser than a particle of cream of the same size, is pressed outward by its centrifugal force more forcibly than the particle of cream. Thus, therefore, a great centrifugal force is used in place of gentle gravity to generate a great difference in centrifugal pressure, and thus quickly force the separation of the water from the cream.

In a very analogous way, the drier in a modern laundry, whirling rapidly around, separates the water from the wet cloth by centrifugal action.

So, also, the whirling atmosphere of the earth drives cold air from the north pole toward the equator, pushing aside the warm south winds.

Among the many branches of physics that are studied in the laboratory, none has more interest than the flow of metals, whether elastic or non-elastic. All that we have learned about this subject has found immediate application, first, in the improvement of the ancient process of wire drawing, second, in the modern process of rolling rails, again, in the still more modern process of drawing the seamless tubes, and, finally, in the rolling of the immense plates for our ironclads.

The steam locomotive is often said to have begun with the work done by Oliver Evans, of Philadelphia, in 1772. The improvements made by George Stevenson, of England, for a while gave English engines a high position as models; but since those days Philadelphia has come to the front and the Baldwin Locomotive Works are now sending their engines to England herself. You all know from personal experience that the modern locomotive embodies at every point the best thought of investigating physicists and illustrates again the absolute necessity of securing for our inventors, engineers and manufacturers the best graduates of our best technical schools.

You will not, therefore, be surprised if I emphatically urge upon your attention the general principle that the relation of astronomy and physics to the mechanic arts is not wholly an historical one, in that astronomy and physics preceded and fostered all important improvements, nor is it merely one of dependence, in that astronomy and physics look to the mechanician for the perfect apparatus. It is not merely a relation, but a relationship and a close one. It is a twinship, in fact, a Siamesian twinship where the blood of each flows through the other. If art is the right hand, science is the left. If one is the tool, the other is the worker. Neither advances without the other; if one steps forward to-day, the other steps forward to-morrow.

Among the most important features of the development of modern mechanics has been the introduction of a class

of machinery sometimes designated as machine tools, by which we mean machinery that is more or less perfectly automatic and is designed for the construction of many copies of some one part of another machine rather than for the direct manufacture of crude material as in textile work. These parts were formerly made entirely by hand; they were forged or filed, sawn and hammered, scraped and polished until they were of the proper size, shape and smoothness. A watch, for instance, is a machine intended to keep correct time; every portion of it, from the minutest screws and pivots to the chasing on the outside of the cover, was formerly done by skillful hands and the expenditure of time and labor was enormous, while the resulting mechanisms always presented minute differences, such that no two similar parts of two watches could be interchanged. Now, however, tools are available by which every part of the watch is made by machinery. The human hand and eye scarcely ever intervene, the similar parts are always interchangeable and the resulting watches are, to a very great extent, perfectly comparable with each other in their performance as time-keepers. Just as a file is a simple tool in the hands of the workman, so the Waltham lathes, planing machines, engraving machines, screw-cutting apparatus and drilling machines are *complex* tools, namely, machine tools, for manufacturing the parts of the watch.

The history of the modern development of the mechanic arts is the history of the application of the highest science to the perfection of the machine tools.

But a machine tool may be almost useless without the steady supply of power necessary to drive it. The foot-lathe is a simple machine tool, but it cannot be applied to fine work on a very large scale, such as that now required, owing to the unreliability and irregularity of the power that is used as the prime motor. The development of the modern lathe and its application to innumerable problems was necessarily dependent upon the invention of the steam engine, the turbine wheel and the dynamo, all of which furnish an abundant and perfectly equable supply of power that can easily be transmitted to any desired spot.

Among the important machine tools we may quote the lathe as applied to the cutting of screws and the production of all manner of symmetrical surfaces; the planing machine for flat and curved surfaces; the drilling machine for cylindrical pits; the boring machine for hollow tubes. Modifications of the lathe are seen in the vertical drilling machine and the slot-drilling machine. The machinery for making the blocks that are used in connection with tackle was one of the earliest machine tools. The trip hammer, as modified by Nasmyth into the steam-hammer, works as if endowed with intelligence. The rivet machine replaces hundreds of laboring men, but makes it possible to set thousands at work on other lines.

A very important class of tools is that for testing and measuring the dimensions and the fitting of the various parts of a machine. When once a perfect machine or tool has been made, there immediately comes a demand for perfect copies of it, and these cannot be made without accurate measuring machines and machine tools that are correspondingly accurate. The great advantage to be derived from the system of manufacture in which each part of a machine is identical in size and shape with the similar parts of other machines was appreciated in England many years ago and was especially insisted upon by Sir Joseph Whitworth. The perfect measuring machines that are necessary to carry out this idea have, however, been manufactured and used most freely in this country, William Sellers and Brown & Sharpe being well known in this work. The average errors of properly made interchangeable parts of a machine will not, in the present state of the art, exceed $\frac{1}{1000}$ part of an inch, and even in the largest cylinders and pistons of a steam engine freshly turned out of a huge lathe there ought not to be an error of $\frac{1}{100}$ part of an inch or the ten thousandth part of their own diameter. Still greater accuracy can be attained whenever needed.

Some of the heaviest and, at the same time, most accurate machine tools are those built for the purpose of manufacturing heavy ordnance, armor plate and the machinery of the great naval vessels of the world. In the construc-

tion of these the best engineering talent and the soundest scientific knowledge are always utilized. They illustrate the best that can be done at the present time; but who can tell what another year may bring forth?

We have spoken of the mechanic arts as though we have to deal only with working tools and moving machinery; but, of course, all great stationary engineering structures being themselves the products of the mechanic arts, illustrate, on the one hand, the perfection to which the arts have attained, and, on the other hand, the physical problems that must be solved in the course of this progressive development of the arts. Within our own lifetime we recall such monuments as the tubular bridges over the Menai Straits and over the St. Lawrence, the suspension bridges over the Niagara and the East Rivers, the London Crystal Palace of 1851, the Eifel Tower at Paris and the Ferris Wheel at Chicago. These were only possible after machinery had been devised for rolling the iron and steel, cutting and bending it, punching and twisting it in all directions, and, finally, testing every portion of the structure as to its strength and expansion with stress and temperature. Even in the fine arts, our pianos, organs and brass instruments respond to the increasing knowledge of physics and the finer arts of the modern mechanic. Only the violin remains as yet unimproved by the progress of the mechanical arts.

Perhaps the modern bicycle illustrates, in a small way, that which the dynamo and electric motors do in a large way, the fact that at every turn our knowledge of physics is of vital importance to our future progress. It is about thirty years since the first French bicycles made their appearance. The idea, that is to say, the invention, was ingenious, but it was impossible to popularize this vehicle in its first crude stage. The wheels were simply those of a small ordinary wagon; the tire was iron for the sake of durability; both front and back wheels were too large, so that an unnecessary strain was brought upon the rider, which proved disastrous to many. Since those days successive changes have taken place; the iron tire is replaced by the india rubber pneumatic tube; the heavy wheel of

the wheelwright gives place to the elegant steel wheel and frame; the chain and sprocket give place to perfectly bevelled cog-wheels and rods. The fatiguing journey then indulged in as an athletic exercise now becomes the regular and easy work of an hour in discharge of one's daily duties, to say nothing of touring for pleasure, day after day, all summer long. Every step in this progress has been, and every step in future development will be, but an application of principles discovered and taught in the physical laboratories of our universities.

VIII. EDUCATION IN SCIENCE AND TRAINING IN ART ARE MUTUALLY HELPFUL.

If science both stimulates the arts and feeds the artisan with necessary physical data; if the laboratory of the investigator and the workshop of the artisan are thus intimately associated together, how is it with the young men themselves who are to become either artisans or scientists? How is it with the education of our youth? Fortunately, laboratory practice or the teaching of physics by means of systematic personal experimentation in appropriate laboratories has been introduced into all of our best institutions of learning. It is now clearly recognized that the only satisfactory education is that which gives the student both a knowledge of the discoveries of others and personal practice in the art of discovery. The study of nature is not conducted by haphazard methods, but is itself a highly developed art. The courses in practical arts and the courses of scientific study should not be widely separated, but should be considered as being essential portions of one course of education.

In an address delivered in 1883, at Johns Hopkins University, the Hon. S. T. Wallis said that no phrase illustrates the action and reaction of the practical man and the scientist upon each other better than that due to Mr. Huxley: "While all true science begins with empiricism, it is true science only in so far as it strives to pass out of the empirical stage into the deduction of empirical from more general truths." The average citizen imagines that the learned man

of research is set apart from everyday life. He needs to be reminded daily that the electric light, the incandescent Welsbach, the brilliant acetylene, the ordinary gas light are all evolutions which the practical world owes to the physical laboratory; that not only the electric motor, with its halo of mystery, but the ordinary steam engine, which is but little less mysterious to the uninitiated, and the turbine wheel, which everyone imagines he can admire intelligently, are wholly the creations of the practical scientists who have given of their knowledge freely to the world of mechanic arts.

We must not attempt to separate investigation and education from invention and manufacture. We need to bring them closer and closer together than ever. I may quote from Dr. Wallis the case of a fireman or engineer of many years ago, in the days when the explosions of boilers were more frequent than now, and were an important object of investigation by the Franklin Institute. His boiler had exploded disastrously; he was called upon to give his testimony and proceeded to state that "no one could know anything about these things except a man who had been brought up in the boiler room, and that the particular explosion in this case was, undoubtedly, due to the gases in the boiler." When asked what gas, he replied with an air of triumph: "How can I tell? I was not inside the boiler." Fortunately, such ignorant men are not now allowed to have control of boilers and human lives. Safeguards and protective devices of all kinds have been attached to the boilers, and, indeed, all other kinds of machinery; but, after all, the essential element of protection lies in the training and intelligence of the men in charge. It will be a happy day when every university has attached to it a school of mechanical engineering, so that the practical world of action and work may profit all the more by the scientific wisdom and broad learning of university scholars.

These crude remarks of mine will, perhaps, have already accentuated the importance of a thorough education along mechanical and physical lines, if one intends to devote his life to the improvement of the mechanic arts. As I have

said before, one may, by a fortunate and accidental collocation of ideas, be put in the way of making an important invention or improvement; but the chances are all against this unless one has been pursuing such a course of education and training as will have fitted him to recognize the importance of the ideas when they suddenly occur to him, and to embody them appropriately in the metal and material of which his machine is to be made. Many a bright thought occurs to those of us who have not trained skill in the art of composition, and, therefore, we fail to become poets and musicians; many a man witnesses daily some little operation going on about him, but fails to make it the basis of a new process in the mechanic arts, because his thoughts do not run that way. In general, the most important improvements in machinery originate with those whose daily work familiarizes them with the special subject and its needs. It is fortunate that the tendency of the present generation is very decidedly toward the thorough education in physics of those who inherit a liking for machinery, in the belief that thereby they will certainly be better prepared to contribute toward the advance of our arts and to compete with those who, throughout the world, are revolutionizing the progress of civilization. America holds its own with England and Europe in this respect.

The following prominent training schools may be mentioned:

The Sheffield School of Engineering, at New Haven, founded in 1847, but in 1860 changed to the Sheffield Scientific School of Yale University.

The Lawrence Scientific School, with its recent addition of mechanical engineering, founded in 1847, at Cambridge, Mass.

The Massachusetts Institute of Technology, founded in 1861.

The Worcester Polytechnic, founded in 1865, at Worcester, Mass.

The Packer School of Engineering, Lehigh University, Bethlehem, Pa., founded in 1866.

The Stevens Institute, at Hoboken, founded in 1868, opened in 1871.

The Sibley College of Mechanical Engineering and the Mechanic Arts, at Cornell University, Ithaca, N. Y., founded in 1870.

The Case School of Applied Science, at Cleveland, O., founded in 1877.

The Rose Polytechnic, at Terre Haute, Ind., opened in 1883.

The graduates of these institutions are now everywhere coming to the front in our workshops, in the Patent-Office, in the manufactories and even in our politics, for, of course, the practical mechanic and engineer must be represented in the State and Federal legislatures.

I notice that in Germany both merchants and manufacturers have lately united in stimulating the education of mechanics and artisans as an important step toward improving the quality of their goods and the condition of German trade. The manual training schools, the workingmen's trade unions, and other interested parties in the city of Hanover have resolved to establish advanced lecture courses, in which artisans and apprentices in all trades shall have an opportunity to complete their education in mechanics. Only those will be admitted to the classes whose theoretical and practical knowledge is such as to give promise of success. Great care will be taken to teach young men how to obtain the most practical advantages from the knowledge imparted in the classes. A permanent exhibition of all power machines and tools will be established.

The needs and opportunities of a great technical college were forcibly set forth in 1893, in an article by Dr. R. H. Thurston, Director of the Sibley College at Cornell. After enumerating the large sums of money devoted to the support of educational institutions, he called attention to the fact that technical education in the mechanic arts, strictly so-called, had not—and we may still say *has* not—been sufficiently provided for. The present demand for trained electricians but emphasizes the great need of training in every department of the mechanic arts. The provision for culture in literature, history, pure science and the fine arts is far better; but that for technical instruction, manual training

and the art of doing as well as thinking still calls for attention. Laboratory or engineering research is especially to be desired. Every piece of machinery that we are using to-day is in itself a field for investigation as to whether it is doing its work with the greatest efficiency and in the best manner possible; but such investigations demand a previous knowledge of the laws of mechanics and familiarity with mathematical methods such as the technical schools alone can give.

The passage of a nation from barbarism to modern civilization occupies a long time, and is always attended with a great increase in density of population, and a great rivalry between individuals competing for success. The interaction between all classes of the community grows more intense; those who are on top struggle to keep their vantage by calling to their aid all the resources of power and intelligence. Experience has demonstrated that in this contest intelligence wins, and that knowledge is power. There can, therefore, be no doubt of the wisdom and statesmanship of the community that improves every possible opportunity to develop the natural resources of its territory and the intelligence of its own citizens. Both in Europe and in America universities and surveys, arts and manufactures, morality and science, health and prosperity go hand in hand. Victory flies to those who are best prepared; peace rests with those who nurture the arts of peace.

President Eliot has nobly said: "It is the regular pursuits and habits of a nation in time of peace that prepare it for success in war and not the virtues bred in war that enable it to endure peace."

From this point of view—the highest that any philosopher has yet attained—we see at a glance the wisdom of those citizens who have encouraged the development of both material and intellectual resources. I join the material and the intellectual together, for neither is of use without the other. If it is the mind that studies nature, it is also the mind that conquers nature. The intellect is developed, strengthened and quickened in this struggle with nature. A university includes every possible variety of education,

theoretical and practical: mechanics and physics, the laboratory and the workshop. It stores up knowledge but only to diffuse it again in perennial streams.*

[Remarks of Prof. A. S. Mackenzie, Bryn Mawr College, "On the Claims of Abstract Science to a Place in the Frank lin Institute."]

PROFESSOR MACKENZIE:—Professor Abbe has given us to-night a beautiful example of the value of theory when turned to practice; we all know of his researches on clouds and the clearness of the earth's atmosphere, but to-night he has descended from the clouds and shown his power to provide with a clear atmosphere the subject of the relation of pure science to the mechanic arts. I have listened to his remarks and those of Professor Mendenhall with very great pleasure, but with a good deal of trepidation, for I fear that what I may have to say will but traverse the ground they have already so fully covered. Perhaps, however, I may be pardoned some repetition, for I believe that too much stress cannot be laid on the importance of the subject upon which Professor Abbe has chosen to address us, and that progress in the future is to be made only by the theorists and the practical men keeping in the closest touch with one another's aims and needs.

It seems to me that the event in the history of the Frank-

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* Even while this was being said in Philadelphia, a most favorable endorsement of these views was offered elsewhere, in that a stirring letter from Andrew Carnegie turned the subscription lists for the new University at Birmingham, England, very decidedly towards the promotion of applied science rather than merely literary and scholastic work. The immense iron and steel interests that center in Pittsburgh owe their development to Carnegie's foresight in securing young scientific experts to manage each department of his works. He urged that Birmingham should make science the principal and classics the subsidiary department of education; that the Midlands might retain its prominence as the British manufacturing center.

The question is not one of markets or of transportation, but of skill and economy of manufacture. He who has such a thorough understanding of chemistry and physics that he can manufacture the best article, will be sure to find a market and to overcome the difficulties of transportation. "Knowledge is power."

Mr. Carnegie's great gift to Birmingham will surely redound to the benefit of the whole English-speaking world.

lin Institute which we are assisting at to-night is a notable one in its progress, and one which shows the high ideals of the Society and the broad aims of those to whom its management and direction are entrusted. We learn from the full title of the Institute that its aim is *the promotion of the Mechanic Arts*, and we read of its sections devoted to Mechanical, Electrical, Chemical, Mining and Metallurgical Engineering as a matter of course. At first thought it might cause surprise that it had a section devoted to theoretical chemistry, and that it was proposing to add a Physical and Astronomical Section; it is, however, but living up to the many-sided character of the man whose name is so intimately connected with it, and whose investigations in the realm of abstract science are an integral part of our studies of to-day; and I think that not until now can the Franklin Institute be said to have reached the standard set by its founders, or to have been quite rounded out in its various functions.

The line of progress and development of the Society has been a natural one in this new and rapidly-growing country, where the production and improvement of appliances for the rapid development of the country's enormous resources have called to their aid the best thought and energies of its people. As a consequence, the technical side of science has been advanced more rapidly than its theoretical side; it is true we have had a Franklin and a Henry, but the production of such men has been spasmodic, and until quite recently the study of physical science was but nominally existent in this country, whereas now great strides forward are being made and the names of Rowland, Newcomb, Gibbs, Michelson, etc., are known in every corner of the scientific world. It is more than a coincidence, I think, that to-day the Franklin Institute is forming a section devoted to Physics and Astronomy, and that the physicists of the country meet at New York to-morrow to found an American Physical Society; it proves that at last there is an awakening to the necessity of the study of science for itself, and to the belief that we are fit for better things than to be a nation of shopkeepers and inventors only.

To the problems of engineering and technical science in its widest sense the Franklin Institute has in the past devoted most of its energies, and with great and growing distinction; the inventor or thinker to whom a John Scott or other medal of the Institute has been awarded has a recognized standing the world over, and the Journal of the Institute is consulted regularly by all engineers who wish to keep abreast of the progress in their special fields, and to follow the newer and more important processes and developments of their chosen work. But surely it is not necessary to add that, insomuch as it has not had among its sections one devoted to the study of physical science for itself, without thought of material gain or useful adaptation, it has lacked one very necessary part of an advanced organization devoted to mechanical science. I consider it a great privilege to be present at this auspicious opening of the Physical and Astronomical Section. The able address of Professor Abbe, whose reputation, already so well known, will not suffer from the interesting lecture we have just listened to, has emphasized the absolute necessity of a close communion between the men who are willing to be the devotees of pure science and those whose ideals are in a direction equally valuable, and the results of whose labors are felt directly by each one of us at our every turn. It is upon this necessary working together of these two groups of men that I think we should at this meeting lay stress.

A science must exist before applications of it can be made, and hence the two divisions of the great work fall into the hands of two different sets of workers; and the nature of the work and the composition of mind required are quite different in the two cases. Not to the pure scientist belongs all the credit for the making of a science; the mechanic or engineer can, by constant thought and application, so get at the very heart of things that he becomes a coworker of the theorist and advances our knowledge of the inner workings of nature; for a mathematical knowledge is not essential, it is a help and a valuable one, and the man armed with this weapon for attacking a problem is at an advantage, provided he does not become lost in his sym-

bols; and it must not be forgotten that Faraday wrought out his great work in the field of electricity without mathematical equipment of the higher variety. It is, however, to the theorist, not to the technical man, that we must look for the advancement of science; but this advance can never be so rapid as it should be unless both theoretical and technical men recognize their mutual dependence. Du Bois Raymond has somewhere remarked that there is no abstruse investigation into nature that does not at some time have its practical application, and, this being so, how essential it is that this investigation should proceed on a clear knowledge of the work done and being done by practical men. Perhaps no better illustration of the value to the theorist of a knowledge of the technical requirements of his subject can be found than in the development of the study of thermodynamics; it was the work of Watt and his successors that led to the brilliant achievements of Carnot, Kelvin, Clausius, Maxwell, Hirn and others. Our whole knowledge of the laws of energy is almost a consequence of the researches called into being by the demands of engineers to know the principles underlying the working of the heat-engine. The theorist thus receives a constant guidance and check as well as incentive, and is forced to give a reality and definiteness to his speculations which might otherwise remain in the clouds and whose full significance would be known not even to himself.

But to the technical man the assistance of the theorist is of much greater value. In addition to the direct aid afforded to the engineer by the new principles and discoveries of the thinker must be mentioned the fact that the theory not only guides the engineer in the direction of possible development and improvement, but that it acts as a beacon to warn him from the many directions in which his genius and labor would be barren of results, because he aims at the impossible.

There never was a time when, more than now, the technical man must work hand in hand with the pure scientist. It requires the finest theoretical knowledge to devise a telegraph by the aid of which eight or more mes-

sages can be sent along a single wire in each direction at the same time, and yet we ordinarily consider telegraphy a purely technical subject. The engineer who would keep up with the pace which science is making must consider himself always in the schools; he must be trying to keep step with the changes in the theory and with the growth of knowledge as proclaimed from the studies and the laboratories; he must, if he would win distinction, have the training which fits him to seize the idea behind the theorist's symbols and forms, and strikingly apply it to the everyday problems in which his interests and labors lie.

The brain of the genius who can fasten upon the practical consequences of an idea brought forth by the mere thinker is one of the very highest order, and he deserves the merit he receives, and the world is quick to reward him in its substantial way, although the world is little able to discriminate, and is willing to believe the scribbler of any magazine article who prophesies plausibly a sudden demolition of the laws of nature which the labors of the greatest thinkers have placed on the most enduring bases. Just now we can see an example of such a thing with regard to the law of the conservation of energy; we are threatened with most improper doings by liquid air, and we have not yet forgotten the Keely motor. It is to the credit of the scientist that he is willing to give his life to the prosecution of learning for its own sake, and that, too, when an understanding and appreciation of his labors must be given to few. How common it is to hear that man who has made some application of value (measured in money or utility) lauded above the originator of the idea. One hears of this or that inventor of the electric lamp or dynamo, but not of Faraday, who made an electric arc fifty years earlier, and produced the electric current by induction and foreshadowed all its applications. One hears of a Hertz or a Marconi, with their electric waves and wireless telegraphy, but how seldom of a Clerk Maxwell, whose seething brain put forth the thoughts of which these things are but adaptations. How often is Lord Kelvin's name connected with the problem of submarine cabling? One is almost tempted

to say that the person of so-called average intelligence gives in his heart greater credit to the inventor of "see that hump?" than to the discoverer of the law of gravitation. Surely equal credit must be given to the originator of an idea with him who applies that idea to the purposes of mankind; and it must come home to us how necessary is the existence of a close bond between these sets of workers, so that each aids the other and to each is given the credit which is his due.

Now I believe that not only will the founding of a physical and astronomical section bring about good results of this kind to the Franklin Institute, but I consider that it is only a beginning in the direction in which such an institution should be expanded. It should have its staff of professors, whose only duty it should be to pursue original investigation, and the results of whose work should be made known to the world through the Society. Of course such things cost money, and being a practical people we hesitate to give our money to what we please to call unpractical purposes. I hope, however, that we have come to the conclusion that a full return for the money so spent is bound to come back to us in overflowing measure, though in indirect and unseen ways. It seems that our benefactors who give of their wealth to advance education are unwilling to pay for pure science; they willingly give their money to found and endow libraries, they give freely to art collections and to museums; but what cases can we recall of the founding of a laboratory for research only, a place where a Rowland could be put and told to go ahead regardless of expense and enrich the world's treasure-house of thought? The German Government has such an institution, and yet I would be sorry to see ours try to imitate it; for it would be difficult every four years to find a man of the right political complexion to take a well-earned turn at the "job." At the Reichsanstalt, to which I refer, and with which Helmholtz was connected in his later years, is a vast equipment, with its experts, to be counted not by units, but by hundreds, who devote their time not only to standardizing apparatus, but also to the devising of the best and simplest

forms of instruments and to the production of new ones; and in addition to all this is Professor Kohlrausch, with a staff of fifteen or twenty assistants, whose only aim is original research in the field of physics. All the products of these men's brains and the results of their labors are given freely to the world. I know of nothing similar in this country in the domain of physics; Harvard College has one of its departments, the astronomical observatory, devoted entirely to research. Professor Pickering and his associates give no lectures and no instruction in the observatory; they are expected simply to use their best efforts to promote our knowledge of astronomical science, and to this end are provided with a staff of forty assistants, and a fully-equipped observatory and library. What better thing could be done by one of our moneyed men, eager to utilize his great wealth for the good of mankind, than to found, in connection with this and similar institutions, a professorship in physics, assuring to one qualified to fill it a liberal stipend (for even a Newton must eat) and all the appliances and assistants his genius can employ?

Perhaps this has carried us too far into the future, and whether we shall ever come to this I do not know; but at any rate I believe that the Franklin Institute has made a move to-night which will redound to its credit and usefulness, and I have taken great pleasure in being present at its inception.

[Abstract of remarks of Dr. T. C. Mendenhall, President Worcester Polytechnic Institute, Worcester, Mass.]

DR. MENDENHALL spoke substantially as follows:

"The excellent and carefully prepared address of Professor Abbe leaves little to be said by those who follow him. It is a real pleasure, however, to be able to congratulate the Franklin Institute on the realization of a plan which is a recognition, tardy though it may be, of the intimate relations between the mechanic arts and physical science, or, as some of us would be inclined to say, the dependence of the former upon the latter. When I read the subject for discussion I wondered how it could be a subject of discussion at all, for I am sure everybody knows and admits

that progress in the mechanic arts rests upon and is measured by progress in the physical sciences. But it is no ordinary event in the history of either that the Franklin Institute, which may be justly considered the foremost organization in the country, whose primary object is and always has been the higher development of the mechanic arts and the encouragement of American invention, has organized a special section for the better development of its interest in the physical sciences. When one reflects upon the splendid work of the Institute in its chosen field, the outlook for the future of this new section of physics and astronomy is most promising, and we are all confident that much important work will here be done.

It is impossible to speak in this hall without constantly-recurring thoughts of the pioneers of American science.

It is entirely natural that the present should appear to be the golden age, and among the historians of science in this country it is too common to pass over the seventeenth and eighteenth centuries as relatively unimportant.

As a matter of fact, some of the most brilliant of America's contributions to science were made before the beginning of the nineteenth century and, counted in proportion to the population, the number of eminent scientific men in those days was fully as great as now, and along some important lines their share of the world's work was greater. Perhaps the first contribution from America to the proceedings of a scientific society was the first communication of Gov. John Winthrop, of Connecticut, to the Royal Society of London, of which he was one of the earliest members.

Another Winthrop, of the same stock, Prof. John Winthrop, of Harvard College, was also a frequent contributor, and doubtless did more to kindle and keep alive the fires of colonial enthusiasm for physical science during the eighteenth century than anyone else. But the one great figure of that period was one whose name and deeds are inseparably related to this city and in whose memory this institution was founded. The world has produced few, if any, more brilliant men than Benjamin Franklin. It is with

only one phase of his intellectual activity that we are interested to-night, and in that alone, as a physicist or natural philosopher, no one will deny that he must be reckoned among the very foremost. There is one quality of his scientific work to which I want to invite especial attention; it is the almost ever-present practical end towards which nearly every investigation was directed. On account of the great lustre of his researches in electricity, it is often forgotten that he enriched nearly every department of physical science, and although he evidently did not lack capacity for that keen enjoyment of discovery which depends upon discovery alone and is indifferent to practical results, it is everywhere evident that with him the possibility of turning a scientific experiment or principle to good account as a means of bettering the condition of his fellows was paramount. There is a certain class of scientific men, not large and not increasing, we are glad to note, among whom it is the fashion to speak with what they believe to be a "fine contempt" of applied science, and who, having never succeeded in discovering anything of any particular value or use, pride themselves on pursuing science for the sake of science. And we have all heard of the mathematician who thanked God that he had at last discovered a formula of which it would be utterly impossible ever to make any practical use. But this doctrine has not been held by those most entitled to distinction in the annals of science, and Franklin was a notable example of those who believe that the noblest ambition by which a man of science may be stirred is the ambition to discover laws which may be utilized in the amelioration of the almost necessarily harsh conditions by which mankind is surrounded.

It is difficult to address a body of scientific men in this place without thinking of another great name, that of one who stood almost at the beginning of that long and unbroken line of astronomers for which our country is justly famous. And in thinking of Rittenhouse in Philadelphia one is likely to turn from the contemplation of his splendid career as an astronomer to that incident, so characteristic of the men of his time, in which the man of science became, at the

behest of the Committee of Safety, the clockmaker again, designing and casting clock-weights in iron which were to be exchanged with the inhabitants of the City of Brotherly Love for leaden weights, to be moulded into bullets, which contributed to the founding of a new nation. During the life of that nation the most marvellous changes have been wrought in the material condition of man and his relations to the planet which he inhabits. We have ourselves witnessed so many of these changes that detailed reference to them is unnecessary, but we may profitably inquire concerning the underlying cause of such a prodigious revolution. To my mind it is found and found only in the discoveries in physical science, and in their application to the control and direction of the forces of nature. Man lives in this world only by the continued transformations of energy, and his comfort and happiness depend largely on the amount of energy he is able to transform. It is not long since his only supply was that furnished by the muscles of his own body, but during the nineteenth century he has been able, thanks to physical science, to draw upon almost inexhaustible sources from without, and this is why he has progressed by leaps and bounds that have exceeded the most extravagant imaginings of our ancestors. This progress cannot be attributed to war, for war has existed since the dawn of history, and it has failed to lift man above the slavery of unintelligent toil. Nor is it due to religion, nor literature, philosophy or art, for all have flourished for ages without materially altering the relation of man to his environment. Science, with its unerring processes of observation, experiment and precise measurement, has inaugurated the peaceful revolution in social relations and material conditions which the nineteenth century now passes on, still incomplete, to the twentieth.

The pen has conquered the sword, but the yard-stick is potentially the master of both.

Mechanical and Engineering Section.

Stated Meeting, held Thursday, March 9, 1899.

MECHANICAL APPLICATIONS OF COMPRESSED AIR.

(Abstract of remarks by Mr. W. L. SAUNDERS, M. Am. Soc. C. E., Member of the Institute, in opening the discussion.)

(*Continued from p. 55.*)

The profile of the One-hundred-and-twenty-fifth Street line shows that the grades to overcome fairly represent average conditions in New York. The grade from Fort Lee Ferry east to the Boulevard being 1·96 per cent., while at the New York Central Railroad tunnel crossing the maximum grade is 7·7 per cent. for a short distance, which is just as difficult to start the car upon as a long grade of the same ascent.

In the following statement of operating expenses, the coal and water items include all that has been used at the compressing plant during this period, and the labor account includes, in addition to the operating employés, a night watchman, record keeper, and also switchman for a portion of the time. It must also be borne in mind that the fires are kept under boilers for twenty-four hours, although the compressor only runs seven hours daily.

Actual average cost per car mile for entire period—seven months—125·16 miles per day:

Coal	$0.0563
Water	.0103
Oil and Waste	.0013
Power Plant Labor	.1261
Conductor and Motorman	.0608
Repairs Car Equipment	.0038
	$0.2586

Average present cost per car mile, with one-car service performed—78·09 miles per day:

Coal	$0.0675
Water	.0113
Oil and Waste	.0017
Power Plant Labor	.0833
Conductor and Motorman	.0608
Repairs Car Equipment	.0038
	$0.2284

Average present cost per car mile, with two-car service—156·18 miles per day:

Coal	$0.0433
Water	.0103
Oil and Waste	.0013
Power Plant Labor	.0833
Conductor and Motorman	.0608
Repairs	.0028
	$0.2018

If the proportion of labor actually utilized in this service is considered, the expense would only amount to $0.1791 per car mile at present.

Present number of employés, six besides conductors and motormen.

The reason for the present cost of operation being lower than the average for entire period is that the number of employés has been reduced, in addition to a less air consumption by the car. The number of employés at present is, however, sufficient to operate a fifteen-car service, so that the proportion of labor charges per car mile is still very high.

At a recent conference of several engineers, who investigated the cost of operating the American Air Power Company's system in behalf of a street railway now operating a large number of cars at intervals of one minute, it was determined, after careful examination, and agreed that for the items above enumerated the cost per car mile would in no event exceed $0.085, and that with a large equipment of cars in a service like that performed on One-hundred-and-twenty-fifth Street the cost would only be $0.0756 for the same items now costing $0.2018, while operating the two-car service. This would make the total operating expense of such a road about 12 cents per car mile.

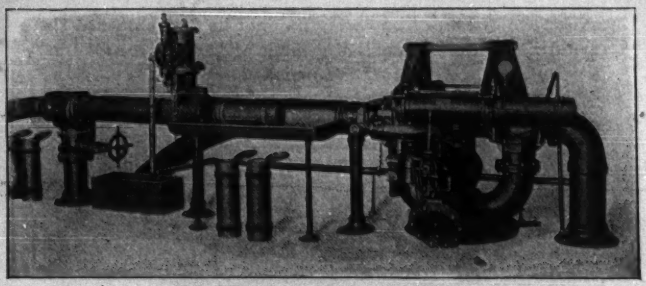


FIG. 12.—The Batcheller system of pneumatic dispatch. Sending apparatus and open receiver, Produce Exchange Line, main post-office, New York City.

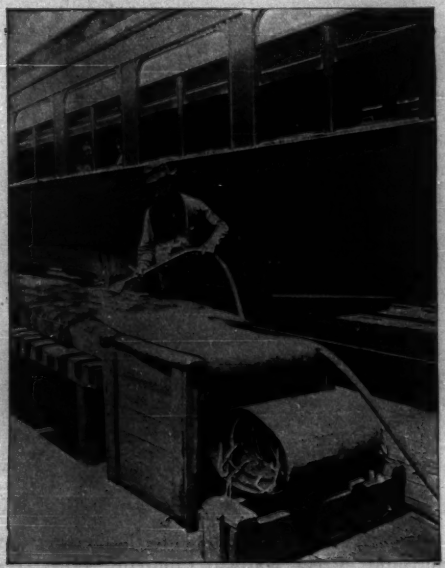


FIG. 13.—Cleaning car cushions and carpets by compressed air.

For the benefit of any who may not be familiar with the operating cost of so small a number of cars by mechanical power, the following data is furnished:

In the recently published report of the operating ex-

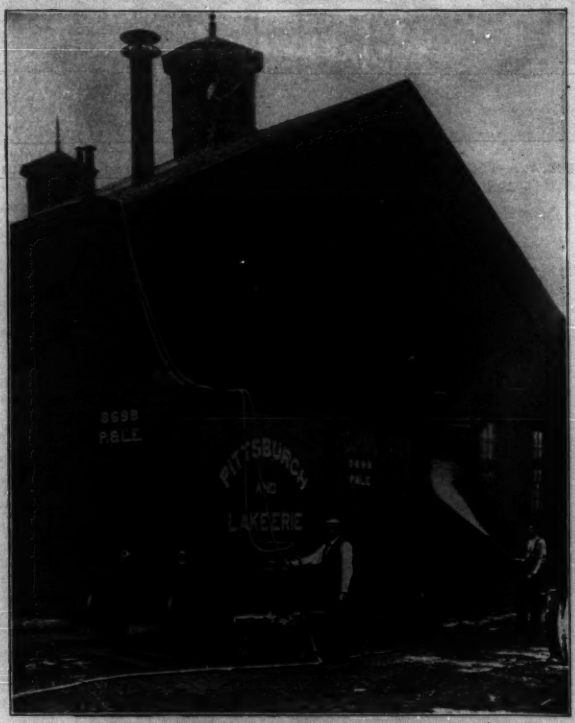


FIG. 14.—Painting by compressed air.

penses of twenty-two electric roads in Connecticut for 1896, the West Shore Street Railway Company, West Haven, is reported as operating precisely the same mileage, namely, 4·11, with the same number of cars in service, having, how-

ever, only five employés, and the average cost of operation per car mile is shown as $0.2991.

In the published report referred to, the average cost of

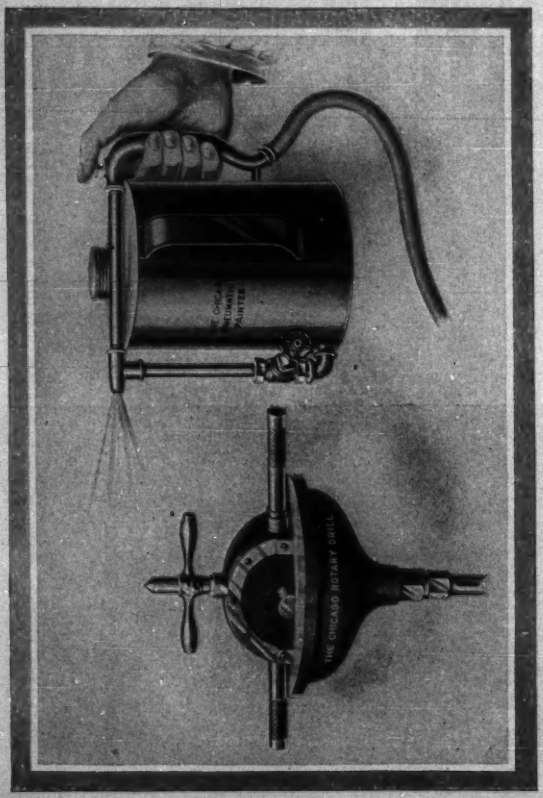


FIG. 15.—Painting by compressed air.

operation per car mile of the twenty-two roads given is $0.1444; and in the twenty roads having the items of mo-

FIG. 16.—Granite surfacing machine.

FIG. 17.—Sand-blast in operation.

tive power, and line repairs given, the average cost appears as follows:

Motive Power, Average	$0.02816
Line	.00270
	$0.03086

The average consumption of free air per car mile for the seven months' service of air cars on One-hundred-and-twenty-fifth Street has been 477·7 cubic feet. During the severe snow storm of December 16, 1896, the cars performed

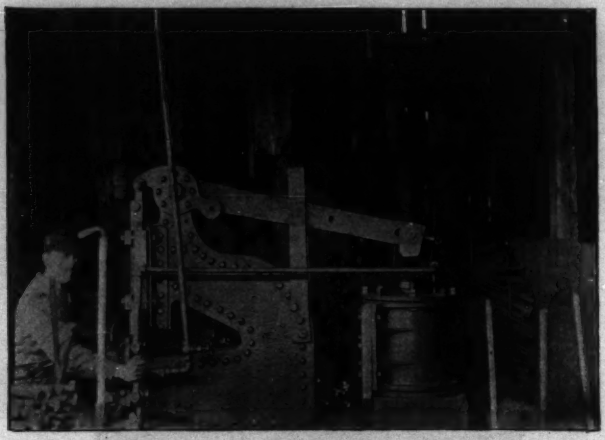


FIG. 18.—Pneumatic scrap shears.

the schedule service with promptness and regularity, carrying 20 per cent. more passengers and using 22 per cent. more power than the day previous. In comparing results with an electric road in this vicinity, it appears that, with 33 per cent. less service than the day previous, the load on the power-plant was about 80 per cent. greater.

During the last week the average consumption of free air per car mile was only 414 cubic feet, and many of the trips were made on considerably less than 400 cubic feet.

The actual cost of compressing air to 2,500 pressure per square inch, and storing for use in a modern air compressing plant operating with condensing engines, including coal at $2.75 per ton, water at $1.00 per thousand cubic feet, oil and waste, the removal of ashes, labor, repairs and maintenance of power plant, depreciation, and interest on cost of entire power-plant including buildings, for compressing plants of the following capacities, based on the consumption of 2½ pounds of coal per hour, per horse-power for twenty hours per day, will not exceed the following figures:

FIG. 19.—Surfacing railroad track by means of compressed air.

Cost per 1,000 cubic feet of free air compressed to 2,500 pounds pressure per square inch:

Station Capacity.	
500 cubic feet per minute	$0.0675
1,000 " "	.0571
2,000 " "	.0469
3,000 " "	.0419
4,000 " "	.0394
5,000 " "	.0375
6,000 " "	.0359

Station Capacity.			
7,000 cubic feet per minute			$0.0342
8,000	"	"	.0326
9,000	"	"	.0312
10,000	"	"	.0300

Responsible parties will guarantee that the cost will be less than stated, and the writer believes that the cost in highest grade plants can be reduced fully 25 per cent.

Assuming the average consumption of air per car mile can be kept as low as at the present time, the average cost

FIG. 20.—Pneumatic punch.

of motive power per car mile on the above basis would range from $0.0124 to $0.027, or an average of $0.0197; and even if 477·7 cubic feet, the same as averaged for the past seven months in regular service, the cost of motive power per car mile will range from $0.014 to $0.032, or an average of $0.023. Placing these figures against the cost of motive power as averaged in the Connecticut electric roads for 1896, the results seem to show considerably in favor of compressed air as a motive power.

This cost of motive power, based on twenty hours' service,

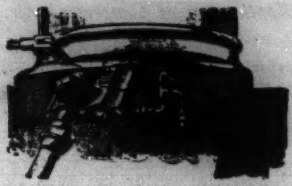


FIG. 21.—Pneumatic track-sander.

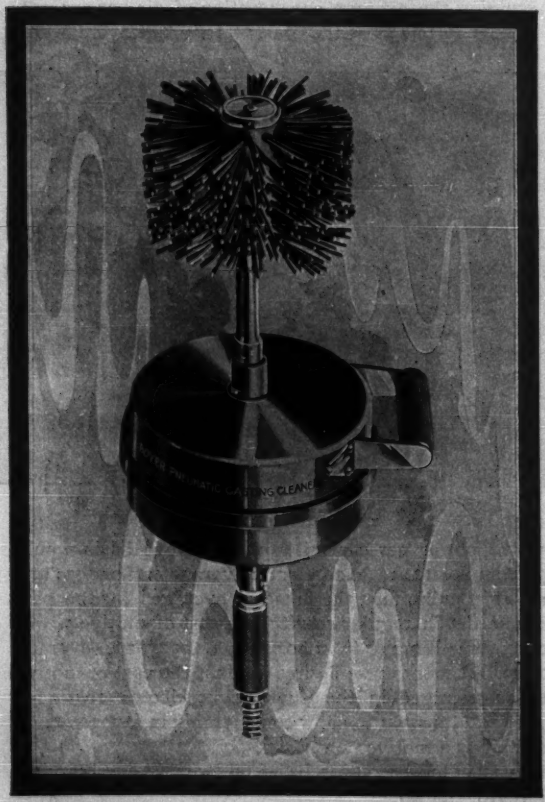


FIG. 22.—Pneumatic casting cleaner. Weight, 10 pounds.

does not represent the lowest cost that is available for the different capacities in the best practice for this reason, that in a compressed air plant having station storage reservoirs for accumulating the air, the engines can be

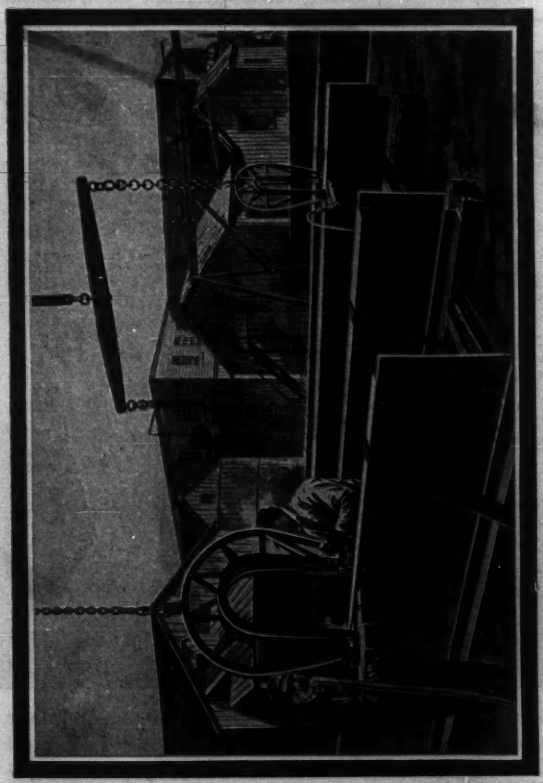


FIG. 23.—Pneumatic riveter.

worked at a uniform load at the most economical point of cut-off for, say, sixteen hours, after which the engines may be shut down and the power-plant charges stopped.

At the One-hundred-and-twenty-fifth Street compressing plant, the engine is operated only about seven hours daily, while the cars perform a twelve-hour service from a seven-hour station duty.

The process of operating the compressed air system on One-hundred-and-twenty-fifth Street is as follows:

FIG. 24.—1¼-inch Keller pneumatic hammer, caulking seams of high pressure digesters.

The air is first compressed by a steam-actuated air compressor, which is compounded in three stages from which the air passes through a cooler and dryer and is accumulated in a nest of Mannesmann steel flasks, which are all con-

nected in multiple by a series of headers or manifolds, in which stop valves are placed for controlling and confining the air to be stored at a maximum pressure of 2,500 pounds per square inch. A pipe leads from this air storage to the car house charging stand, placed alongside the track, which consists of a copper pipe in three sections, having a

FIG. 25.—View of pneumatic stone hammers at work on statuary.

controlling valve and flexible joints and a charging nozzle at the end. All the joints and the nozzle are self-packing, so that no leakage has occurred in the seven months' service. After the car has been connected by inserting the nozzle in a pipe at the side of the car track, the charging valve is opened and contents of the station storage flasks admitted

until the desired pressure—2,000 pounds per square inch—is registered by the car storage gauge. Then the charging valve is closed, and a small bleeding valve in the charging pipe opened, permitting the high-pressure air in the short length of pipe to escape, at the same time a check valve in the car piping closes automatically, preventing any escape of air, after which the nozzle is removed and the car ready for another seventeen miles' service. The entire time occupied, including connecting and disconnecting in actual daily service, takes less than two minutes, and has been done in less than one minute in numerous trials.

[*To be concluded.*]

Mining and Metallurgical Section.

Special Meeting, January 25, 1899.

MALLEABLE CAST IRON—ITS HISTORY IN THE UNITED STATES.

GEORGE C. DAVIS.

Malleable cast iron may be roughly defined as occupying a half-way position between ordinary gray cast iron and wrought iron, as it possesses some of the qualities of both. This definition is not technically accurate, but serves rather to designate the place occupied by malleable iron in the commercial world.

Ordinary cast iron is a very complex alloy of iron with carbon which exists in several forms: silicon, phosphorus, manganese, sulphur and small proportions of other elements. As we all know, it can readily be cast into intricate shapes. It cannot be bent or forged, and it is brittle under shock, especially in light sections. Wrought iron, in its most refined form, is practically pure iron, and can be easily forged, and can be bent or twisted even when cold without fracture. It cannot easily be cast, but can be welded, a property not possessed by cast iron.

Malleable cast iron, or malleable iron, as it is commonly

called, is made from pig iron low in silicon, sulphur and phosphorus, and from which the carbon has subsequently been largely removed by annealing at a red heat in iron ore, mill scale or some other porous or infusible substance. When cast the iron is white in fracture and as brittle as glass, owing to the carbon which is present to the amount of about 3½ per cent., being in chemical combination with the iron. During the annealing at a red heat, the carbon, which is at this temperature in a state of solution in the iron, gradually diffuses. As it comes into contact with the surrounding packing it is oxidized and passes off as a gas which can be seen burning at the cracks in the clay luting of the pots. There is a variable amount of carbon retained in the casting, but it exists in a form like graphite in ordinary cast iron, that is to say, it is disseminated throughout the mass somewhat as mica occurs in granite. The flakes of graphite lie between the particles of iron, and form, as it is said, "planes of weakness." The diffusion of carbon in iron, even at a bright red heat, takes place slowly, and hence only castings of small cross-sections can be decarbonized to any appreciable extent. In castings less than ¼ inch in diameter practically all the carbon can be removed.

We have, then, as a result of the two processes, casting and annealing, a product which has first been formed in any desired shape and by its subsequent treatment converted to a state approaching wrought iron. We should therefore expect its physical properties to be between those of cast and wrought iron, and this we find to be the case. Its tensile strength, 45,000 pounds to 52,000 pounds per square inch, is more than cast iron, but slightly less than wrought iron; its elongation of 3 to 7 per cent. is much greater than cast iron, which is practically *nil*, and much less than wrought iron. We find, on trial, that malleable iron can be bent or twisted and forged to some extent, but not so much as wrought iron. The preceding remarks apply to light work, say to an inch in thickness or less. It is proper at this point to speak of another function of the annealing process as applied to heavy work, such as castings for farm implements and car couplers. As before stated, castings of this

class cannot be decarbonized to any appreciable extent, but they are rendered soft and strong. Such articles cannot be bent as much as the decarbonized castings, owing to the graphite forming planes of weakness, as noted above. We have, then, two classes of malleable castings, the small decarbonized articles and the larger articles containing nearly all their original carbon, but in a changed form. Each class of castings is admirably adapted for its own purpose. It may be questioned, if both classes are equally strong and soft, why is it necessary to decarbonize the smaller castings merely to increase their toughness? The answer is that in small work this quality is essential. Many small articles (bits, for instance) are cast open and "closed up" after inserting a ring; or, in assembling bits, parts are frequently upset or headed like a rivet. Thus, for small work it is highly desirable to have decarbonized iron to obtain the bending and cold forging properties.

Little has been written of the history of malleable cast iron, and, so far as I am aware, no account has ever been published of the beginning of this industry in the United States. I will endeavor to describe the practice in earlier times, the difficulties encountered, and will briefly mention some of the earlier foundries. The first malleable iron castings of domestic manufacture were produced in Newark, N. J., in 1826. Seth Boyden, to whom belongs the honor of doing this, was a native of Foxboro, Mass., but settled in Newark, in 1815, when in his twenty-seventh year. As a boy he worked at farming and occasionally at a furnace operated by one of his uncles. He attended school for only a few short terms, but this by no means ended his education, for he continued his studies by himself, especially in those natural sciences that would aid him in his labors. He showed to a very marked degree the traits of the stock from which he sprang. Mechanical ingenuity and skill with tools came to him naturally. During the course of his long life he was occupied with many of the arts and sciences, and so great were the benefits conferred by his many inventions and improvements on existing processes, that the citizens of Newark have erected a statue to his honor. Much

of the apparatus with which his experiments were conducted was made by his own hands. He made, among other things, a telescope, microscope, electrical apparatus and engraved a label for his books. Such work as this was usually done at odd intervals, or after the regular work of the day was over, and was to him rather recreation than serious business, but it serves to show his versatility. Many claims have been made for him as being the inventor of various processes. His original inventions were numerous, but his best and certainly, from a commercial standpoint,

Seth Boyden, Inventor.

the most important work was done in perfecting the ideas of others. There are few inventions which are not in dispute, and it is often the case that after learned men have written articles proving to their satisfaction their own side of the case, the archæologists step in and state that the Chinese or ancient Egyptians knew all about the article in question several thousand years before Christ.

Boyden is credited with inventing a machine for making wrought iron nails, a machine for making brads and files, a

machine for cutting and heading tacks and a machine for splitting leather. He also made the first patent or glazed leather, as it was then called, produced in this country, and carried on quite a business in this article for some years in supplying harness-makers. He built locomotives and made many improvements in their designs. In this connection it is interesting to note that he built a locomotive called the "Cometa," for the Cardenas Railway, of Cuba, and went there himself, in 1841, to put the engine in operation. One of his most important inventions was a machine for forming hat bodies, which he patented. This was the only patent that Boyden ever took out. In later years, when old age had incapacitated him for active business, he turned his attention to raising new and improved varieties of strawberries, and succeeded in this as in other things. It was characteristic of the man that a problem once thoroughly mastered, he turned his attention to some new process. He seemed to care only for mechanical success, any profits he might derive from his labor being merely useful to enable him to experiment in some other line. It seems incredible that he should have accomplished so much, but his life during the threescore years in which he was actively engaged is a good illustration of the endurance and persistence of the hardy New England stock. He took little care to protect his own interests and died, a poor man, in the year 1870.

Soon after Boyden settled in Newark he was engaged in the silver-plating business and it is possible that this was indirectly the cause of turning his attention to malleable iron. A large part of his business was in plating carriage and harness hardware. In those days such articles were necessarily quite expensive, as they were made by hand from wrought iron. It is evident from Boyden's notes that he had learned that such articles could be cast and rendered malleable by annealing, but he evidently knew nothing of the details of the process. General Runyon, in his address at the dedication of Boyden's monument, said: "What is called malleable iron was known before Mr. Boyden discovered it, but he invented it as truly as ever a man invented anything wholly new and previously unknown." This view

has been held by many, but I believe it to be clearly in error, for in experiment No. 6 of Boyden's notes, he says: "A piece of English M. iron was in, but no important alteration." Again, under the date of August 4, 1826, we find the entry, "50 pounds Sprue, 50 pounds Pig, White, when baked a perfect resemblance of some English of the same size." This proves that at about the time Boyden began his experiments he had in his possession some malleable castings that had been made in England.

Let us turn for a moment to note the progress of this industry in other countries. Reaumer had published the fundamental principles of the process in the year 1722, and some years later patents were granted in England for softening castings by annealing in ashes. This process applied to such castings as nails, anchors, cannon, chains, forge hammers, etc. In 1804 Sam Lucas, of Sheffield, took out a patent on malleable iron, but he believed the difficulties to be insuperable and so made no use of his patent in a commercial way at least. His brother, Thomas Lucas, shortly after took up the matter, and succeeded in producing cast cutlery which, according to Parks' "Essay on Edge Tools," 1815, would take as fine a polish as the best cast steel. These articles were sold under the name of run steel. According to Percy and other authorities, the use of malleable castings rapidly extended, and by 1830 the industry had attained large proportions. The castings were used for cutlery, pulley blocks, carriage and harness hardware, and a variety of other purposes. Thus we see that malleable iron had been manufactured in England for some years before Boyden began his experiments.

In 1828, the Franklin Institute of this city offered a silver medal for the best specimen of annealed cast iron, to consist of not less than one dozen pieces. The report of the committee of that Society says: "Premium No. 4, for the best specimen of annealed cast iron, is awarded to Seth Boyden, of Newark, N. J., for specimen No. 163, being an assortment of buckles, bits and other castings, remarkable for their smoothness and malleability. This is the first attempt in this country to anneal cast iron for general purposes that

has come under the knowledge of your Committee, and success attending it, fully entitles the maker to a silver medal." From the wording of this report it is evident that the committee were aware of the manufacture of malleable castings abroad, and in awarding the medal to Boyden it is merely for excellence of workmanship on a novel article. There is no hint in the wording of the report of the process being regarded as an invention of Boyden's, prior or otherwise.

His experiments with malleable iron of which we have record extended over a period of six years. At first they were carried out in his house, the iron melted in a crucible in a forge fire. The castings were annealed in a small furnace, using hard coal, erected in his fireplace. In this way he made a series of twelve experiments to determine the

best pig iron to use, the best packing, proper temperature for annealing, etc. A part of experiment 6 is here shown, which illustrates a series of diagrams used in some manner to keep track of the various mixtures of iron. These diagrams are supposed to refer to the shape of the castings and are possibly cross-sections of them. In some cases we can trace a relation between the shape of the diagram and the proportion of iron used.

One-seventh wrought, six-sevenths Sterling, fine, strong, superior, good before anything I have ever seen.

One-fourteenth wrought, six-fourteenths Sterling, nearly the same as above.

One-twenty-eighth wrought, six pieces Sterling, nearly the same as above; a little darker.

Sprues of above, nearly the same as above; the above bent to less than ½-inch circles.

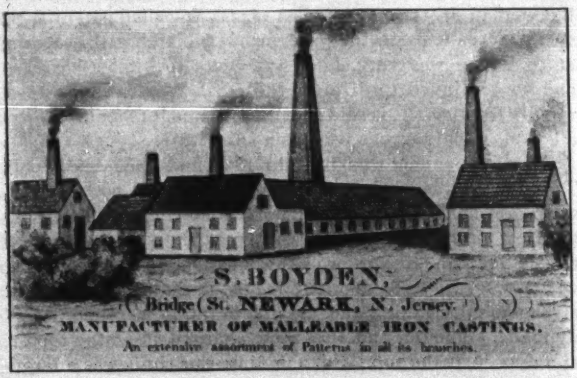
He was sufficiently encouraged by the results obtained to erect a foundry, which was started in the summer of 1826,

for on July 4th of that year is the entry under the heading "Experiments in foundry." His observations and deductions were exceedingly shrewd, though his explanations were often at fault. When we consider how little was then known of chemistry and metallurgy this is not surprising. The selection of a suitable pig iron occasioned him little difficulty, as it is evident from his notes that he very soon came to the conclusion that Sterling was the best. He tried many brands separately and in various mixtures. He mentions Sterling, Peru, Carthage, Bennington, Vt., three brands of Salisbury, viz., R., B. & Co., H. C. & Co., and C., S. & Co.; two brands of Egg Harbor, viz., Etna and Weymouth; Sheldon, Washington, Amenia and Scotch. This latter was soon given up, the notes experiments 10 and 11 stating that it was brittle. The reasons for this we can well imagine. Few of the brands here mentioned are familiar to the foundrymen of to-day. Etna and Weymouth recall to us the industries which once existed in the Jersey pines. The furnaces in this district used bog ore, and their output was mainly devoted to castings. It is of some local interest to note that the first cast-iron water pipe produced in this country was made at Weymouth Furnace, which was located on Great Egg Harbor River, about six miles from May's Landing. This furnace was erected in 1802, and has long since been abandoned. Etna Furnace was situated on a tributary of the south branch of Rancocas Creek, two and one-half miles from Medford, and four miles from Taunton, in Burlington County.—Swank's "History of Iron in All Ages." Of these once flourishing concerns scarcely a trace remains. The decline of this district as an iron-producing centre began about 1840, when Scotch foundry iron began to come into this country in considerable quantities. In the early days castings were made directly from the pig metal, and many furnaces produced little iron in the form of pig. The furnaces in South Jersey were unable to meet the severe competition caused by the cheaper Scotch pig, and the rapid decline and total extinction of the iron industry in that locality followed in the early fifties. The Salisbury Furnaces are probably the only ones now on the active list. The companies referred to,

viz., Richardson, Barnum & Co., Canfield, Sterlin & Co., and Holly & Coffing, all operated plants in Litchfield County, Conn., which is in the extreme northwestern portion of the State. The works owned by the last-named firm was located at Chapinville, and here was built the first blast furnace in the Salisbury district. This was about 1762, at which date Ethan Allen was one of the owners of the property. Holly & Coffing also operated a furnace at Mount Riga, which was probably the one from which Boyden obtained his iron. This furnace began operation about 1810, and was abandoned in 1856. Amenia Furnace was located in Dutchess County, N. Y., twenty-four miles east of Poughkeepsie, and not in Connecticut, as Boyden states in his notes. This furnace began operations about 1770, and during the Revolution (there was in operation in connection with it) a small steel works, which was a source of supply for the Continental Army. The steel was probably made from bar iron by the cementation process. Iron from the Salisbury district was hauled by teams to Hudson or Poughkeepsie and thence transported by water. So far as can be learned iron was not sold on commission, at least in the early days. It was usually sold in very small lots, and dealings were direct between producer and consumer. Payments were made in cash or more frequently in long time notes. The Sterling Iron Works were located in Orange County, N. Y., and were in the early days a very important concern. Here was manufactured the huge chain which was stretched across the Hudson in 1778. Part of this chain is still preserved at West Point. Sterling iron was considered for many years one of the best brands for malleable castings, and was in use for this purpose as late as 1861. The Long Mine, from which Boyden obtained some of his ore for packing, was located on this property. Peru and Carthage Furnaces are supposed to have been located near the towns of the same names in New York State, in the Champlain district.

Passing now to the consideration of the *commercial* features and works' practice during the first few years, we find that the foundry which Boyden erected was located at 28 Orange Street, in the rear of his home on Bridge Street.

It gave employment to about sixty moulders. At first, and for much of the experimental work, the iron was melted in a crucible, heated with charcoal or hard coal. Lime was the flux most frequently used and the iron was frequently remelted. This Boyden frequently alludes to in his notes as "refining." Experiments were also made with fluxing with other substances, such as iron ore, sand, clay, glass and sulphur, evidently with the idea of leaving nothing untried. Some of these were obviously forlorn hopes, as in experiment 9 we find the entry: "Delaware, $\frac{1}{8}$ W.: pounded fine with glass, brittle as usual." Boyden's practice seems


S. BOYDEN,
Bridge (St. NEWARK, N. Jersey.
MANUFACTURER OF MALLEABLE IRON CASTINGS.
An extensive assortment of Patterns in all its branches.

to have been to run the iron very high, for he speaks in a number of places of the iron being "sparkling" and "smoky," the latter term presumably indicating incipient oxidation and a very high temperature. Considering these facts it is somewhat remarkable that no mention is made of shrinkage, which does not seem to have troubled the early founders at all. An air furnace was soon built with a capacity of about 1,000 pounds. The fuel was dry pine wood or soft coal, and it is said that eight heats a day were made, starting at 3 A.M. and often not finishing until late in the evening. This furnace was not tapped, the iron being

dipped out in clay-washed ladles, holding from 10 to 12 pounds each. In the notes June 12, 1828, there is a reference to Virginia coal. This coal probably came from the mines in Chesterfield County, near Richmond. Nichols, in his book, "The Story of American Coals," says: "In 1750 the Virginia bituminous mines were opened and worked, on the James River near Richmond; these mines were the first to be opened for the market in the United States. Owned by an English company and competing only with English coal, they enjoyed for some time the exclusive coastwise trade in the Union. In their nature the coals are very dry and gaseous." These mines are not now worked, but were in operation as late as 1842. So-called patent fuel, coal and rosin, came into use in 1831, March 25th. Rosin at this time was very cheap—75 cents to $1.00 a barrel—and so continued until after the Civil War, when it rose rapidly in price. It is said that at one time it reached $68.00 a barrel. Coal tar was used as a substitute.

The first cupola was built in 1832 and used hard coal. This cupola was of the solid bottom type, and consisted of a straight shaft, the upper part of which could be lifted off to allow cleaning and repairs after a heat. The probable reason for this design was the small size of the cupola, which was said to be about 18 inches in diameter. By this arrangement cleaning and repairs to lining were more easily made. The pig and fuel were charged in at the top or at a door near the top. Surrounding the shaft was a large bell-shaped draft stack. An archway through this stack afforded entrance to the charging platform, with ample room between shaft and stack for the men to work. Such a cupola as this could be operated only every other day, as the cinder and unmelted stock required time to cool so that it could be removed and repairs made to lining. The use of cupolas and air furnaces for melting malleable pig was, up to a comparatively recent date, peculiar to this country, it still being the practice in many foreign works to use crucibles.

[*To be concluded.*]

CHEMICAL SECTION.

(Photographic and Microscopic Branch.)

Stated Meeting, Tuesday, June 6, 1899.

AN IMPROVED MICRO-STEREOSCOPIC CAMERA.

By JOHN G. BAKER,
Member of the Institute.

I have pleasure in showing you this evening a new camera which I have constructed for the purpose of making stereoscopic pictures of small objects.

To accomplish this end has taken much time and a great amount of experimenting. I first fitted up my stereoscopic camera for the purpose, but the result was not at all satisfactory, although I made some very fair negatives with it. The camera proved to be altogether too short, and the lens and object had to be changed from one side to the other, all of which made it very inconvenient. My next attempt is embodied in the instrument I have here this evening for exhibition. It was originally one of Anthony's lantern-slide cameras, which I have altered to what you now see. The shutter used is a 4 x 5 "Victor," made by the Bausch & Lomb Optical Company, of Rochester, N. Y. To the front of this I have fitted an attachment to carry the lens, and also to hold a reflector for properly illuminating the object. In the rear of shutter I have, instead of a lens, a ring, to cut off deflected light that might be caused in its passage through the shutter. The rear end of the camera has been fitted up to receive a 5 x 7 plate-holder, but in such a way that it may be used in two positions, so that each end of the plate may be exposed independently of the other. The plate-holder rests against a partition with an opening in it of a size just sufficient to cover one-half of the plate.

The lenses for very small objects are achromatic objectives that are used in the microscope, but for this work are

changed somewhat, to better answer the requirements. The trouble I found with them for this work was their narrow angle and extremely small depth of focus, and both of these faults had to be remedied before I found it possible to make a satisfactory negative.

I also found that the rays of light, in passing through the lens, had a tendency to fog the plate by coming in contact with flat surfaces, even when these were blacked with the greatest care. I overcame this trouble satisfactorily by dispensing with the flat surface, *i. e.*, by making them on a bevel, with only the sharp edge to reflect the light. To do away with the difficulty arising from the small depth of focus, the only way was to stop down the lens.

Now, as the depth of some objects is very great in proportion to the focal length of the lens, I was compelled to use a very small stop. (I use the word *stop*, as I understand it to mean an aperture placed close as possible to the lens.) The smallest stop I use is $\frac{1}{1000}$ of an inch in diameter, with the edges of the opening made very nearly sharp and carefully blacked. The rear of the lens has also to be guarded, to prevent deflections, which in this work would be very serious.

Of course, the time of exposure requires to be lengthened in proportion to the size of stop; the smallest stop sometimes requires as much as forty-five minutes, and as each exposure must be separately made on the plate, the time will be doubled, making, for the two exposures, ninety minutes.

Now, in regard to the object to be photographed. Let us suppose it to be a small insect. I place it in a bottle containing cyanide of potassium, which soon ends its life; I then set it up on its feet in a position as nearly life-like as I can, on a small piece of opal glass, and, to hold it in position, I fasten each of its feet down by means of wax; this is done by using a very small tool, heated in the flame of a spirit lamp. After the feet are fastened properly, the surplus wax is carefully removed by scraping it away with a fine-pointed knife. The object now is ready for the camera, and upon the pedestal, in front of the lens, the mounted object is made

fast. Now, this pedestal, upon which the mounted object is fastened, has a rack-and-pinion movement, so as to elevate the object to the required height, and has also a ball-and-socket joint on the top, so that the object can be placed in any desired position. The image on the focusing glass is brought in position horizontally, by sliding the lens and board, which can be done by turning the milled head on the top of the camera.

Now, to make the exposure. After everything is ready, I place the object in its best position, and focus as sharply as possible, with the image in its proper place on the ground glass. On the front end of the camera, at the bottom of the pedestal, is a small milled-head screw, which should be turned until it brings up against the shoulder under the camera. This arrangement is for the purpose of permitting the removal of the lens from the object, and its return again to exactly the same place, so that there may be room to change the stops. The reason for doing this is, that after the small stop is in place, it is impossible to see any image whatever on the ground glass.

Now, I fasten front and rear of camera (after the proper stop has been put in place) by means of the clamp screws at the side, and run in the plate-holder until it drops into the first groove, then set the camera in position with the reflector facing a northern sky, and make the first exposure.

After the first exposure is made, the stop is removed and upon the pedestal will be found a graduated circle, divided into parts of 5° each, and also a pointer. This pointer is now to be moved around one of the graduations from left to right, and then the image on the ground glass again placed in position. The stop is put in place, plate-holder is returned and run back as far as possible until it drops into the second groove, and the exposure repeated for the other end of the plate. By revolving the object in the direction just mentioned, the negative itself is made stereoscopic and can be placed in the scope and examined to see if it is perfect.

For objects that are nearly the full size of the picture wanted, I use a pair of wide angle 4 x 5 lenses.

THE NATIONAL EXPORT EXPOSITION

FOR THE ADVANCEMENT OF AMERICAN MANUFACTURES AND THE EXTENSION OF THE EXPORT TRADE.

To be held under the auspices of the Philadelphia Commercial Museum and the Franklin Institute, September 14 to November 30, 1899.

The Franklin Institute will signalize the seventy-fifth year of its life by its active participation in an exposition unique in the commercial history of the United States, in that it will be devoted exclusively to the display of American manufactures and products suited for export. It will be the first conspicuous national event of the kind to mark what thoughtful readers of the signs of the times recognize as the advent of a new era in the manufacturing and commercial history of the country; the period when the first successful steps were taken which resulted in the establishment of a world-wide market for the products of American manufactures.

The exposition will be opened on September 14 and will be closed on November 30, 1899.

In the following the principal facts of interest in connection with the enterprise are briefly set forth :

The first public announcement regarding the National Export Exposition, to be held in Philadelphia next fall, was made at a dinner given at the Art Club, on October 11, 1897, by Daniel Baugh, the Club's President.

Dr. William P. Wilson, Director of the Philadelphia Museums, now the Director-General of the Exposition, in an address at the dinner, stated that the idea of the exposition originated from an exhibition held in Providence, R. I., in June, 1897, for the benefit of the foreign delegates to the meeting of the Advisory Board of the Philadelphia Commercial Museum. This meeting was attended by fifty delegates representing the commercial organizations and governments of sixteen of the Latin-American republics. The exhibition at Providence contained the manufactured products of that city and the State of Rhode Island. The exhibits covered a wide range and were of the greatest interest and value to the visitors from the republics to the south of the United States, who were the guests of the city of Providence nearly three days. Dr. Wilson urged that, in connection with the next meeting of the International Advisory Board of the Museum, it would be advisable to hold in Philadelphia a national exhibition of manufactured goods of the United States especially suitable for export, under the joint auspices of the Philadelphia Commercial Museum and the Franklin Institute.

During the two months following frequent meetings of those interested in the project were held, and the many questions involved in the organization of so great an enterprise were discussed. The Bourse, the Drug Exchange, the Grocers' and Importers' Exchange, the Board of Trade, the Commercial Exchange, the Trades League and other trade and commercial organizations of the city passed resolutions commending the enterprise and pledging their support.

On December 28, 1897, the Philadelphia Exposition Association was incorporated at Harrisburg, under an act which provides for the incorporation

of companies not for profit, organized for the encouragement of the arts and sciences. The first meeting of the incorporators was held on the last day of December, 1898, and organization was effected by the election of Mr. P. A. B. Widener as President and Mr. W. W. Foulkrod and Dr. William Pepper as Vice-Presidents. Committees were appointed, and the project was taken up with enthusiasm and a determination to make the exposition successful.

The agitation which preceded the war with Spain, in the early part of 1898, interfered greatly with the plans for holding the Exposition in the fall of that year, and in February, war with Spain being apparently inevitable, it was decided to postpone the opening of the exposition until the spring of 1899 or the fall of the same year.

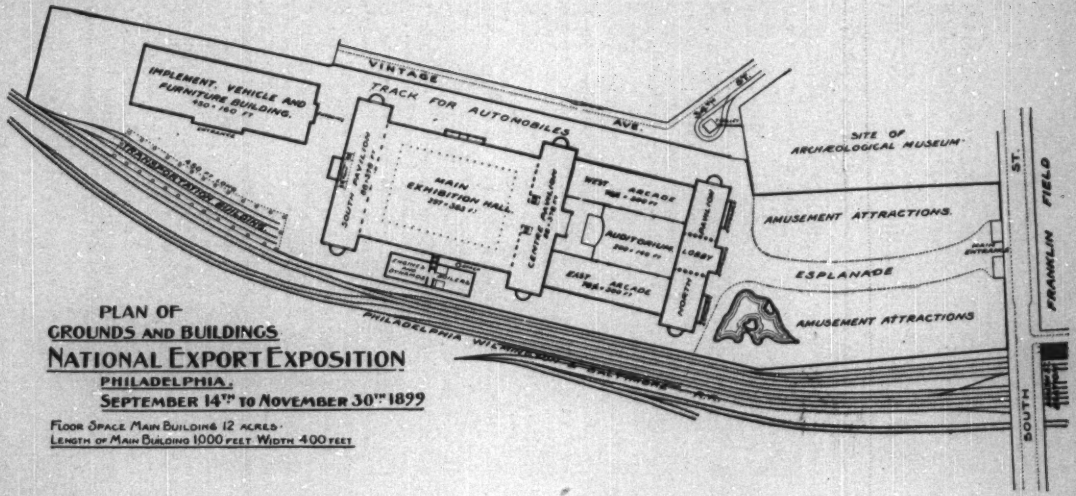
Early in February, 1898, at a meeting of the joint committees of the Philadelphia Exposition Association and the Franklin Institute, the plan for the exposition, as outlined by Mr. William Harper, Chief of the Bureau of Information of the Philadelphia Commercial Museum, was approved. A joint committee of fifteen, composed of five representatives of the Commercial Museum, five of the Franklin Institute, and five named by the Exposition Association, was appointed to organize and generally supervise the plans for the exposition. The committee consists of the following members:

P. A. B. Widener,	Wm. L. Elkins,	Henry R. Heyl,
Chairman.	John Birkinbine,	Henry Howson,
James M. Dodge,	Theodore N. Ely,	Sydney L. Wright,
First Vice-Chairman.	J. C. Strawbridge,	T. B. Wanamaker,
Wm. P. Wilson,	George V. Cresson,	F. Lynwood Garrison,
Second Vice-Chairman.	W. W. Foulkrod,	William Harper.

In the latter part of March, the United States Senate passed a bill appropriating $350,000 in aid of the exposition. The rush of preparations for war with Spain in April of last year in Congress, and the disposition to set aside or cut appropriations for anything but war expenses, prevented the passage of the bill appropriating money in aid of the exposition by the House of Representatives, and after the war broke out its friends concluded that it would be inadvisable to make any further effort to push it.

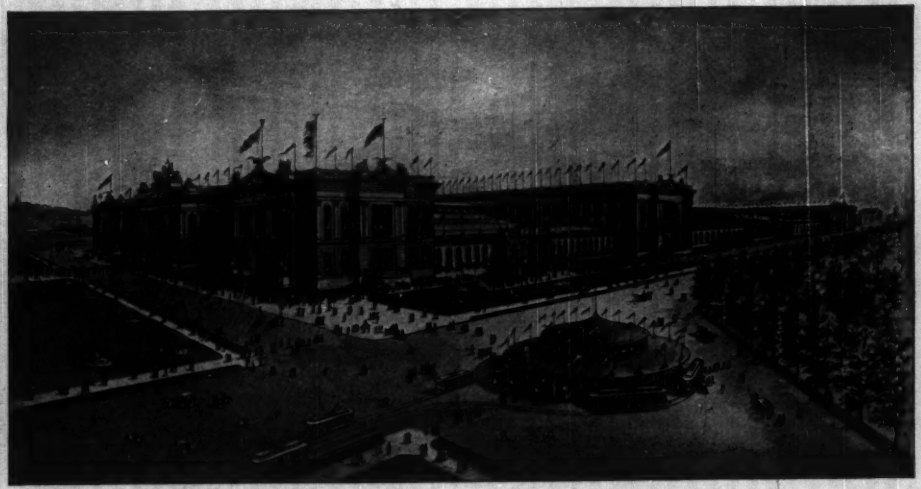
During the spring of 1898 a loan of $12,000,000 was authorized by the City Councils of Philadelphia, for public improvements, $200,000 of which was set aside for the construction of permanent buildings for the Philadelphia Museums on a site already given to the institution by the city in West Philadelphia. It was proposed by the projectors of the exposition to use the buildings which this money would construct in connection with the exposition. Objection was made by certain influential interests in the city to the loan, and the legality of its issue was forced into the courts.

The outlook in the fall of 1898 was most discouraging, but the exposition management energetically took up the work of inducing the National House of Representatives to pass the appropriation bill of $350,000, which had been favorably acted on by the Senate in the spring. On December 19th the bill passed the House of Representatives after a warm discussion. The officers of the Exposition Association felt that the passage of the appropriation by Con-



PLAN OF
GROUNDS AND BUILDINGS
NATIONAL EXPORT EXPOSITION
PHILADELPHIA.
SEPTEMBER 14TH TO NOVEMBER 30TH 1899

FLOOR SPACE MAIN BUILDING 12 ACRES.
LENGTH OF MAIN BUILDING 1000 FEET WIDTH 400 FEET



Main Building, National Export Exposition—September 14–November 30, 1899.

gress, carrying with it the sanction, encouragement and support of the National Government, was an assurance of success for the exposition, the opening date of which, owing to the delay in action by Congress, had been changed to the autumn of the present year.

Dr. William P. Wilson, Director of the Philadelphia Commercial Museum, was elected Director-General of the Exposition Association, on January 6th, of the present year.

It early became evident that the litigation over the city loan would prevent the holding of the exposition unless City Councils stepped in and by a temporary loan or some other expedient provided the $200,000 which the city had agreed to give. When the emergency was placed before the city authorities, they at once arranged for a temporary loan. The $50,000 appropriated by the State in 1897 left but $50,000 to be raised in other ways to meet the conditions of the Congressional appropriation. This was raised in a few weeks by private subscription. The exposition authorities at once opened offices, awarded the contract for the construction of the Exposition buildings, and set in motion the work of preparing for the first National Exposition of American Manufactures for the Expansion of Export Trade.

The exposition grounds are admirably situated, being easily accessible from all parts of the city both by electric car and steam railroad lines. The grounds are on the west bank of the Schuylkill River, within ten minutes' ride of the City Hall, and comprise a tract of land, fifty-six acres in extent, deeded to the Philadelphia Museums by the city of Philadelphia, and another tract of six acres secured for the uses of the exposition and providing a main entrance from South Street at the northern end of the grounds. Electric cars from every section of the city run on the various streets adjacent to the exposition grounds, and a station of the Pennsylvania Railroad, at which all trains will stop during the exposition, is located within 400 feet of the main entrance. Within a few squares are the passenger stations of the Philadelphia & Reading and Baltimore & Ohio Railroads.

On either side of the broad avenue leading from the South Street entrance to the main buildings, numerous quaint and ornate structures will be devoted to illustrating the life, manners and customs of strange peoples, and to other amusement features of a less instructive but no less entertaining character. Broad avenues surround the grounds on three sides, and the Schuylkill River flows by them on the east. Nearby are the buildings of the University of Pennsylvania, and West Philadelphia, one of the most beautiful of the city's residential sections, stretches to the westward.

The main group of buildings is so constructed as to form one imposing structure about 400 x 950 feet in extreme dimensions, and covering an area of more than eight acres. Five separate buildings enter into this large edifice, which has been constructed largely of brick and steel, and upon lines which the experience of other expositions has proven to be desirable.

The Agricultural Implement and Machinery Building will be devoted exclusively to a comprehensive exhibit of agricultural implements, tools and machinery, in the manufacture of which American factories excel. This building will be 400 feet long and 160 feet wide.

A special structure for exhibits of locomotives and railroad rolling stock, electric cars and equipment for electric railways, is called the Transportation

Building. It is 450 feet long and 75 feet wide. containing four tracks connected with the Pennsylvania Railroad. The length of track available for exhibits of rolling stock will approximate 1,800 feet. Other buildings for special exhibits or lines of trade are advantageously located, and there is every promise that they will prove to be among the leading attractions of the exposition.

Of the five structures comprising the main exhibition buildings, three are permanent, but will only be completed at the present time sufficiently for the purposes of the exposition. These three permanent pavilions will have two stories. They will each be 380 feet long and 90 feet wide. The space between them will be covered by temporary buildings, connected with the pavilions, the whole forming a single harmonious edifice. The permanent buildings will eventually become the home of the Philadelphia Museums.

The temporary building between the northern and central wings will be 300 x 297 feet. It will comprise an auditorium and music hall 250 feet long and 140 feet wide, with arcades for exhibits on each side, 300 feet long and 70 feet wide. Between the central and southern pavilions there is an immense area for exhibits 383 x 297 feet in size, covered by a wide expanse of roof supported by trusses resting on columns. The exhibition spaces on the first floor of the pavilions will open into the main hall through wide arches, so that the entire area of 167,200 square feet, 563 x 297 feet in dimensions, will be practically a single open space.

East of the central exhibition hall and connected with it is the exposition power plant, 190 x 58 feet in size. It is adjacent to the Pennsylvania Railroad tracks, affording excellent facilities for handling heavy exhibits. Engines, pumps, air-compressors and dynamos are located in one end of the power-house, and in the other the boilers.

The entrance to the main buildings is through a broad lobby 60 x 90 feet in size, in the centre of the northernmost wing. Handsome columns and decorations and groups of statuary will embellish the lobby. To the right and left, wide aisles lead through the exhibition spaces of the north wing, turning at right angles through the arcades on each side of the auditorium into the central exhibition hall and its wings.

In the auditorium, which will have a seating capacity for more than 5,000 persons, the sessions of the International Commercial Congress will be held, as well as the conventions of various trade and business organizations which have arranged to hold meetings during the exposition.

There are staircases in each wing of the main building leading to the second floor, and it is contemplated that in addition electric and hydraulic elevators and moving staircases will be provided in the form of exhibits. The second floor of the north wing will be occupied by the administration officers of the exposition. In the central and south wings, the upper floors will be given up to exhibits.

A total area of 200,000 square feet of space is available in the main buildings for exhibits. This, with the space provided for in the special buildings, will give American manufacturers ample facilities for a great display.

Running from the main floor of the exhibition hall will be a short flight of stairs rising to the level of the roof of the power-house. This roof will be flat, surrounded by an ornamental railing, and is designed to be used as a

plaza from which visitors may obtain a view of the river, and that portion of the exposition grounds lying east of the railroad track, where windmills, traction engines and all kinds of machinery and farm implements such as are not suited for exhibition in the implement building will be displayed. This space is also available for buildings for special exhibits and for machinery which requires a large space to show it in operation.

From the top of the power-house a commodious bridge will lead across the tracks of the Pennsylvania Railroad, and at the further end a flight of stairs will permit access to the eastern part of the grounds without crossing on the track level.

While the exposition has in view a most practical purpose, there was not, in the planning of the buildings, any idea of completely subserving the beautiful and the artistic to its practical end. On the contrary, the ornamentation and decorations of the structures, though of the temporary character which must of necessity be used in exposition buildings, will be most attractive. Out of a composition, the basis of which is plaster and papier-maché, more durable than the "staff" which made the buildings of the Columbian exposition so beautiful to look upon, have been formed columns with capitals as beautiful as though carved in white marble. Cornices and friezes, panels and screens, the designs of skilled sculptors, aid in giving the buildings rare architectural attraction.

Above the main entrance, a large pediment contains a group of thirteen figures, representing Commerce. Other pediments typify the four continents. Numerous groups of graceful figures allegorical of Transportation, Navigation, Labor, Electricity, etc., rest on pedestals beside the pediments, and over the main entrance there is a large quadrager—a chariot drawn by four horses, carrying a beautiful figure typifying Progress.

One of the most conspicuous events to take place in connection with the exposition will be the International Industrial and Commercial Congress, which will assemble in Philadelphia, beginning with October 10th. A number of foreign governments have accepted the invitation to send official envoys, and many foreign cities, and almost every city of the United States and Canada with a population over 10,000 will be represented by delegates from their Boards of Trade, Chambers of Commerce, etc.

Of special interest to the members of the Franklin Institute will be the ceremonies in commemoration of the seventy-fifth anniversary of the society, which will be held in one of the exposition buildings. The arrangements for this event contemplate a series of commemorative meetings, beginning Monday evening, October 2d, and occupying the entire week. Saturday evening, October 7th, will be Institute Day, and the occasion will be devoted to a general commemorative meeting of the Institute. The evenings of the week will be occupied successively by the Sections in the order of seniority, beginning with the Chemical Section. A feature of these commemorative meetings will be an address or addresses by distinguished specialists. The speakers on Institute Day will be Dr. Robt. H. Thurston and Rear Admiral Geo. W. Melville, U. S. N. For the convenience of members, it is contemplated to install a reading room and general headquarters, where non-resident members will find it convenient to receive mail, and make business or social appointments.

W.

NOTES AND COMMENTS.

A NEW POWER IN PHOTOGRAPHY.

Just when to stop the development of the photographic negative on a gelatino-bromide plate has always been more or less of a problem even to the expert; and as over- is more easily corrected than under-development, it has been the practice, when in doubt, to carry it beyond what was known to be necessary, trusting to reduction to bring the image back to the required density.

For this purpose various methods or reducing agents have been employed, but hitherto they have all had one fault in common—the altering of the values, tonality, or gradation, the most important feature of a negative. This they do in consequence of the fact, hitherto supposed to be inevitable, that reduction goes on equally all over the plate, as much being removed from the delicate detail, in what will be the shadows, as from the denser deposit of the half-lights and lights, resulting in negatives that give prints of the white and black or "soot and whitewash" variety.

Recently, however, the brothers Lumière, to whom photography is already much indebted, have given to photographers a new power in the shape of ammonium persulphate, a solution of which has the property of attacking only, or at least first, the higher and half-lights without touching the weaker deposits in the shadows, thus enabling them to reduce contrasts and secure such values or gradation as they may desire.

It will be evident that with one of the older reducing agents that reduce equally all over the plate, and the new agent which acts only on the denser parts of the image, the photographer may with confidence develop to any degree of opacity, knowing that he has the power, by reduction, to produce any degree of gradation that he may desire.

Hardly less of a problem, especially to beginners, has been how to secure correct exposure; and according to at least one expert, the solution is to be found in ammonium persulphate. It is well known that over-exposure tends to flatness. The negatives may have all necessary detail, but the lights and half-lights are so translucent as to give only weak, flat prints. If, however, ammonium persulphate in conjunction with a bromide be added to the ordinary developing solution, any degree of contrast may be obtained, even to simple white and black, the degree being in proportion to the quantity of persulphate added. For this purpose W. B. Bolton recommends a solution of ammonium persulphate 25 grains and ammonium bromide 5 grains in 1 ounce of water, and a few drops added to the developer. The action will be slower, and the degree of contrast greater, in proportion to the quantity of solution added; but a few experiments will show just what that quantity should be for any reasonable amount of over-exposure.

It may be well to add that the new reducer is not the acid or hydrogen-sulphate, NH_4HSO_4, sometimes called the persulphate, but the true persulphate, NH_4SO_4, said to be produced by electrolysis from the hydrogen-sulphate, thus $NH_4HSO_4 = NH_4SO_4 + H$, the atom of hydrogen being eliminated and the persalt formed at the negative electrode. W.

INFLUENCE OF ANTIMONY IN BRASS.

In a paper before the American Institute of Mining Engineers, Mr. E. S. Sperry has pointed out that the occurrence of cracks during the rolling of brass is due, in some cases at least, to the presence of impurities in the copper of the alloy. In certain investigations made by this author, he added to a brass composition made of 60 per cent. of purest lake copper and 40 per cent. zinc, quantities of antimony varying from 0·01 per cent. to 0·65 per cent., and tested the behavior of the alloys thus obtained in the rolling mill. He found that when the percentage of antimony reached as much as 0·02 per cent. the fracture of the rolled metal indicated its presence. It would appear, therefore, that the presence of antimony in electrolytic copper, the author thinks, is the cause of the unreliability of brass which requires to be rolled. W.

ELECTROTYPES OF IRON.

It has been disclosed that the Austrian and Russian Governments print their bank-notes from steel-faced electrotypes made by the electrolytic deposition of iron from a bath prepared according to the formula of Klein (ferrous and magnesium sulphates) under special conditions of temperature and current-density. This latter must be very small, inasmuch as a plate only 2 millimeters in thickness requires one and a half months for its deposition.

The thin iron electrotypes prepared according to this method are backed in the usual way (with stereotype metal?).

According to Herr Haber, in the *Zeit. f. Elektrochemie*, the advantage of plates prepared in this way lies in the fineness and hardness of the metal, which is first deposited, and in the delicacy of the copy of the original which is thus obtained.

The usual plan of preparing such printing plates—so-called steel-faced plates—is to obtain first a copper electrotype of the original, and then to face this with iron by suspending it at the cathode in the above-named electrolytic bath of Klein, or its analogue. The author declares, however, that the printing results obtained are not nearly so good as when the first method is employed.

A serious disadvantage of the all-steel electrotypes, however, is that they can only be renewed by repeating the entire process of electrotyping, while the iron-faced copper plates can have their faces renewed in a few minutes. W.

THE DRYING OF LINSEED OIL.

Lippert has made some interesting experiments on the absorption of oxygen by thin films of linseed oil on sheet iron.

He finds that raw linseed oil increases in weight slowly for three days, more quickly on the fourth day, and becomes dry on the seventh. The total gain is found to agree closely with that given by Mulder, namely, 12·4 per cent.

Linseed oil, strongly boiled without driers, dries more slowly than raw oil, and is more difficult to manipulate owing to its great viscosity, but eventually it absorbs within 2 per cent. of the oxygen taken up by the raw product. Ordinary boiled oils cannot be compared with raw linseed oil without taking note of the drier they contain. W.

FERMENTATION WITHOUT LIVING CELLS.

As a result of the investigations of Professor Büchner, of Tübingen, another of the fetiches of old chemistry is destroyed, namely, that living cells are necessary to fermentation. Professor Büchner, according to *Science*, grinds yeast with quartz sand in order to disrupt the cells, and submits the moist mass to a pressure of 500 atmospheres. The liquid contents of the cells are entirely removed and the cells totally disrupted. The filtered liquid is of a clear or slightly opalescent, yellowish color, retains the odor of yeast, contains considerable carbon dioxide and some albumen. Most interesting is the behavior of the yeast juice towards sugars, fermentation being set up much more quickly than by yeast, and proceeding much faster. The gas evolved is almost pure carbon dioxide. When carefully dried at a low temperature, the fermenting principle is not destroyed, and it is possible that, when desiccated, the activity of the ferments may be preserved indefinitely. W.

A SIMPLE MEANS OF OBTAINING A HIGH VACUUM.

The use of liquid hydrogen has been proposed by Professor Dewar for the production of very high vacuo. If the end of a closed tube containing air is immersed in liquid hydrogen, the contents of the tube are quickly condensed to solid air, and if the portion of the tube from which the air has thus been removed is sealed with a blow-pipe, a vacuum is obtained so high that it will scarcely allow an electric discharge to pass. This condensation is accomplished almost instantly, the required time of immersion never being more than a minute. This gives a simple means of obtaining the high vacuum necessary in Crookes tubes, and might possibly be on a large scale sufficiently economical for use in incandescent lamp works. W.

ADDITIONS TO MEMBERSHIP.

APRIL 1 to JUNE 30, 1899.

The following persons have been elected and qualified as members of the Franklin Institute during the three months beginning April 1st and ending June 30, 1899:

AGASSIZ, A., Cambridge, Mass.

ALTENRDER, JOHN, 609 Green Street, Philadelphia, Pa., Medical Illustrator.

ASHMEAD, FRANK M., 11 Pike Street, Pittsburgh, Pa., Civil Engineer.

BACON, HENRY DOUGLAS, 4223 Girard Avenue, Philadelphia, Pa., Marine Architect.

BALDWIN, WARD, University of Cincinnati, Cincinnati, O., Professor of Civil Engineering.

BINDER, RICHARD L., 808 North Seventh Street, Philadelphia, Pa., Salesman.

BONNER, JAMES B., 502 Harrison Building, Philadelphia, Pa., Sales Agent Carnegie Steel Co.

BRODHEAD, CALVIN E., Northeast corner Fourteenth and Bushkill Streets, Easton, Pa., Engineer and Contractor.

BUCHHOLZ, CHAS. W., 21 Cortlandt Street, New York, N. Y., Civil Engineer.

BURGDORFF, THEODORE F., care Navy Pay Office, U. S. S "Monadnock," San Francisco, Cal., Chief Engineer U. S. Navy.

BURGWYN, C. P. E., 818 Main Street, Richmond, Va., Consulting Engineer.

BURR, WM. H., Columbia University, New York, N. Y., Professor of Civil Engineering.

CARNEY, JAMES A., Beardstown, Ill., Master Mechanic St. Louis Division C. B. & Q. R. R.

CARR, ALBERT, 19 Amherst Street, East Orange, N. J., Civil Engineer.

CARTER, EDWARD C., care C. & N. W. Ry., Chicago., Ill., Assistant Engineer C. & N. W. Ry.

CHALMERS, W. J., Fulton and Union Streets, Chicago, Ill., President Fraser & Chalmers Co.

COFFIN, JOEL S., care Galena Oil Co., Franklin, Pa., Mechanical Expert.

CONVERSE, W. H., Chattanooga, Tenn., President Converse Bridge Co.

COPPEE, H. St. L., Greenville, Miss., U. S. Assistant Engineer.

DAVIDSON, GEO. M., care C. & N. W. Ry. Co., Chicago, Ill., Chemist and Engineer of Tests.

DAVISON, B. FRANKLIN, 718 Sansom Street, Philadelphia, Pa., Metal Worker and Electroplater.

DEANE, CHAS. P., Springfield, Mass., Mechanical Engineer.

DELANO, WARREN, 1 Broadway, New York, N. Y., Coal Operator.

DICKERSON, WALTER H., care Edison Laboratory, Orange, N. J., Mechanical Engineer.

DIDIER, PAUL, Allegheny City, Pa., Chief Engineer Pittsburg & Western R. R.

d'INVILLIERS, CAMILLE S., Altoona, Pa., Civil Engineer.

DIVEN, J. M., Elmira, N. Y., Superintendent Water Works.

DOANE, SAMUEL E., Hotel Proctor, Marlboro, Mass., Electrical Engineer.

DOUGLAS, BENJAMIN, Detroit, Mich., Bridge Engineer Michigan Central R. R.

DRAKE, W. A., Prescott, Ariz., Chief Engineer S. F. P. & P. Ry. Co.

DUNCKLEE, JNO. B., 601 Eighteenth Street, Washington, D. C., Civil Engineer.

ELDRIDGE, G. M., Defiance, O., Superintendent Defiance Water Co.

FELTON, SAMUEL M., Cincinnati, O., President and Receiver C. N. O. & T. R. R.

FITCH, MAX B., Magdelena, Sorocco Co., N. M., Superintendent Smelting Works.

FITZGERALD, FRANCIS J., care Carborundum Co., Niagara Falls, N. Y., Chemist.

FOLSOM, EDSON F., 1418 Park Avenue, Indianapolis, Ind., Mechanical Engineer.

FORBES, JOHN S., 220 South Fifth Street, Philadelphia, Pa., Mechanical Engineer.

FORD, PORTER DWIGHT, Long Island City, N. Y., Chief Engineer Long Island R. R. Co.

FRIES, C. N. D., 421 Chestnut Street, Philadelphia, Pa., Telegrapher.

GIBSON, JAMES E., care American Pipe Manufacturing Co., Fidelity Building, Philadelphia, Pa., Mechanical Engineer.

GODSHALL, L. D., Ph.D., Nelson, B. C., Canada, Metallurgist.

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HULST, NELSON P., Milwaukee, Wis., Manager of Mines.

JAEGER, A. H., 2236 North Sixth Street, Philadelphia, Pa., Translator.

JOHNSON, J. E., Longdale, Alleghany Co., Va., Blast Furnace Manager.

JUDSON, C. A., Sandusky, O., Civil Engineer.

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MAISCH, FRED. D., 1420 Poplar Street, Philadelphia, Pa., Photographer.

MARSHALL, J. T., Metuchen, N. J., Electrical Engineer.

MAURO, PHILIP, 620 F Street, Washington, D. C., Attorney-at-Law.

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McVean, John J., 71 State Street, Grand Rapids, Mich., Chief Engineer C. & W. M. Ry.

Miller, A. M., 2728 Pennsylvania Avenue, Washington, D. C., Lieutenant-Colonel Corps of Engineers.

Morse, Willard S., Monterey, Mexico, Smelter and Refiner of Metals.

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Parsons, Geo. Wellman, Steelton, Pa., Superintendent Frog, Signal and Switch Department the Pennsylvania Steel Co.

Patterson, Horace H., 3720 Locust Street, Philadelphia, Pa., Mechanical Engineer.

Post, Walter A., Newport News, Va., General Superintendent Newport News Ship and Dry Dock Co.

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Reeser, Otto, 500 North Twelfth Street, Philadelphia, Pa., Machinist.

Saunders, W. F., 26 Cortlandt Street, New York, N. Y., Engineer.

See, James W., Opera House, Hamilton, O., Mechanical Engineer.

Shanks, Thomas P., Little Hickman, Ky., U. S. Assistant Engineer.

Slater, A. B., Jr., Providence, R. I., Engineer Providence Gas Co.

Smith, H. S. S., Princeton University, Princeton, N. J., Professor of Applied Mechanics.

Smith, T. Guilford, Buffalo, N. Y., Civil Engineer.

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Stanton, Rob't Brewster, Sewickley, Pa., Civil and Mining Engineer.

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Walker, J. W., Forty-eighth Street, Pittsburgh, Pa., President Shiffler Bridge Co.

Waterhouse, Addison G., 220 South Fifth Street, Philadelphia, Pa., Mechanical Engineer.

Webster, Albert L., 3 Broad Street, New York, N. Y., Consulting and Civil Engineer.

Whaley, W. B. Smith, Columbia, S. C., Mechanical Engineer.

Wood, Albert, E., Girard Building, Philadelphia, Pa., Mechanical Engineer.

Young, Fred'k Stafford, 11 West Nineteenth Street, New York, N. Y., Civil Engineer.